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The sound of risk and the art of change

Towards a deeper understanding of nuclear risk perception

Inaugural dissertation submitted by Dominikus Vogl in fulfillment of the requirements for the degree of Doctor rerum socialium at the Faculty of Business, Economics and Social Sciences of the University of Bern.

Submitted by

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The faculty accepted this work as dissertation on 23. February 2017 at the request of the two advisors Prof. Dr. Ulf Liebe and Prof. Sandra T. Marquart-Pyatt (Ph.D.), without wishing to take a position on the view presented therein.

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Acknowledgments

For a good friend's ear in Timberlane

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Du dunkelnder Grund, geduldig erträgst du die Mauern
Und vielleicht erlaubst du noch eine Stunde den Städten zu dauern
und gewährst noch zwei Stunden den Kirchen und einsamen Klöstern
und lässest fünf Stunden noch Mühsal allen Erlöstern
und siehst noch sieben Stunden das Tagwerk des Bauern –:

Eh du wieder Wald wirst und Wasser und wachsende Wildnis
in der Stunde der unerfaßlichen Angst,
da du dein unvollendetes Bildnis
von allen Dingen zurückverlangst.

Gieb mir noch eine kleine Weile Zeit: ich will die Dinge
so wie keiner lieben
bis sie dir alle würdig sind und weit.

Ich will nur sieben Tage, sieben
auf die sich keiner noch geschrieben,
sieben Seiten Einsamkeit.

Wem du das Buch giebst, welches die umfaßt,
der wird gebückt über den Blättern bleiben.
Es sei denn, daß du ihn in Händen hast,
um selbst zu schreiben.

I, 61

Dear darkening ground,
you've endured so patiently the walls we've built,
perhaps you'll give the cities one more hour

and grant the churches and cloisters two.
And those that labor – will you let their work
grip them another five hours, or seven,

before you become forest again, and water, and widening wilderness
in that hour of inconceivable terror
when you take back your name
from all things.

Just give me a little more time!
I want to love the things
as no one has thought to love them.
until they're worthy of you and real.

I want only seven days, seven
on which no one has ever written himself –
seven pages of solitude.

There will be a book that includes these pages,
and the one who takes it in his hands
will long sit staring at it,
until he feels you holding him
and writing through him.

I, 61

Berlin, July 2016

Dominikus Vogl

1. Introduction

Two questions were the backbone for writing this dissertation. The first asks: 'What is risk and how is risk perceived in society?' or as I frame it 'What is the sound of risk?' The second question takes a step in a concrete direction. The second question furthermore is pointing towards a specific aim. Hence, the second question is: 'How can a deeper understanding of nuclear risk perception help to create a peaceful and sustainable world for future generations?' In my dissertation I am not able to answer the second question and in truth, I have been challenged to answer the fist one. I have also redefined my questions so they are more precise and can be answered with scientific knowledge and methods. I use all my knowledge, proficiency, respect, and boldness to answer the questions.

In the title I describe risk as a sound. A sound is an impulse that resonates within a given space, like a signal that transmits and changes information (Kasperson et al., 1988). I chose the word sound because it indicates the multifaceted nature of a risk. Something resonates within a given social space and creates a sound that can be perceived and interpreted as a risk. Depending on the impulse, the space, and the receiver the sound of risk is differently perceived within this space. The perception of risk is embedded within a social space and by passing on information the perception of risk is able to change that space from within. A sound is an invitation, an object of change. Sounds are deeply intertwined and cannot be separated from one another – and so are the perceptions of risk. Using the analogy of sound with the concept of risk, I want to invite others to keep thinking of the idea of risk. Somebody can use my work to get inspired and to continue research on this topic.

On an abstract level, I imagine the sound of risk as an invitation to play together; to add new information and above all to listen to each other. In my work, as in my music, I am opening a space for exchanges of ideas. Silence also is a sound resonating in the space of ignorance. A sound can open that silent spaces within our societies allowing to start dialogues and social changes. My hope is that the awareness of nuclear risks keeps a dialogue alive that is constantly working on solutions to improve how social beings live together peacefully today and for future generations.

On a concrete level, pragmatism and curiosity motivated me to want to develop a deeper understanding of nuclear risk perception. The Fukushima Daiichi nuclear accident on March 11, 2011 was a shock for me. I was surprised how little expertise exists among experts and authorities in terms of solutions and protection for affected communities in the area. I was also astounded to see how the accident created a social dynamic in distant places, such as in Germany, that forced political authorities to instantly react to tame nuclear fears. I might have forgotten about this accident had I not been curious about statistical methods, specifically for causal analysis. This interest led to the discovery of a unique situation in the data structure of the International Social Survey Programme (ISSP) and its Environmental Module III (ISSP, 2012), which was the data set I was working with in 2012 analyzing environmental concern. Nuclear accidents happen randomly. Such an unexpected event becomes a cut point that divides the data structure in a pre- and post-Fuksushima sample. The survey was collected in 2010 and 2011. Therefore, the data in the ISSP made it possible to compare respondents' attitudes towards nuclear power before and after the Fukushima accident. I had data, statistical skills, people to advise me, and I wanted to know how the Fukushima Daiichi accident changed individuals perception of nuclear power. However, the question remained: what exactly *is* nuclear risk perception? Holding this question, I started to write my dissertation.

To understand the concept of risk, especially of nuclear, I decided to observe this phenomenon from various perspectives. To do so I step by step chose what literature to include in my dissertation. The order of chapters and topics reflects this approach. Often the chapters are based on one mayor literature source and I let the authors speak in their own voice, presenting their ideas and understandings of risk and risk perception. I also have given some chapters more weight than others. Therefore the weight of perspectives and ideas in my dissertation follows not a well balanced way but sometimes is following one source or perspective in more detail and depth. I wanted to present existing information, expressed and explained by excellent scholars, in a new order to hopefully find new ways of seeing the problem. I would like to inspire other scholars, individuals – including myself – to work on future solutions of how to solve the risk of nuclear energy.

The purpose of my work is to broaden the present view, rather than to explain the existence of risk and risk perception, and the causal mechanisms that create a risk perception. If my work helps to understand causal mechanisms in more detail and supports or rejects existing hypotheses and assumptions, than this is a side product of a more severe question: How to create a world that is free of nuclear threat in the future? This is my underlying intention and goal. The combination of all involved perspectives can maybe reveal the answer for solutions.

As I mentioned previously, my aim is to complement and expand upon the existing work on risk research in social sciences. Excellent people have reflected upon problem from a wide range of perspectives, collaborated internationally, shared and documented their ideas. Take for instance the book: 'The Risk Society *Revisited*: Social Theory and Governance' by Eugene A. Rosa, Ortwin Renn, and Aaron M. McCright (Rosa et al., 2014). Another example is Ortwin Renn's book 'Risk Governance: Coping with Uncertainty in a Complex World' (Renn, 2008). Both book explain the concept of risk from a sociological perspective in a depth I am not able to do. Therefore, my theoretical work will emphasize certain aspects through such authors and their ideas to learn about existing views, and to challenge existing perspectives on (nuclear) risk. This will be followed by my personal empirical analysis on nuclear risk perception.

This dissertation is divided in three parts. The first part, 'The sound of risk,' will develop an understanding of what risk is and how it is perceived by humans. The second and main part of my dissertation, ‘Towards a deeper understanding of nuclear risk perception,’ provides information about existing scientific approaches, in order to explain differences in individual’s perception of nuclear risk. In three empirical analyses, I test theoretical claims and hypotheses on nuclear risk perception in a cross-national comparison, while taking into consideration potential effects due to the Fukushima Daiichi nuclear accident. The final third part, ‘The art of change,’ is included in the dissertation to provide information and to inspire of how to govern risk such as nuclear risk in the future. This work is by no means complete, and clearly, not free of ignorance and error and. There is certainly more work to do, but this is a start.

The following is a summarize of each chapter, including my main sources and authors I have worked with.

1.1. The sound of risk

In Section 2, the concept of risk is introduced and discussed. My first attempt to understand the concept of risk is rimmed within two possible boundaries: a positivistic perspective on the one hand and a constructivist perspective on the other (Rosa, 1998; Rosa et al., 2014). From a positivistic point of view, risks are an ontological reality, an existing entity independent of human’s perception. From a constructivist point of view, the epistemological approach, risks are not an independent entity but are socially created when entering the social space. Through communication, risks take on a social meaning. Here I refer primarily to literature from Eugene Rosa (1998) and Rosa and colleagues (2014). Rosa develops an approach that combines the epistemological as well as the ontological perspective, into one framework, called the “hierarchical epistemology and realist ontology (HERO)” concept (Rosa et al., 2014, 27-32). All knowledge claims about risks are based within these two boundaries of factual knowledge on the one hand and mere interpretation based on non-knowledge on the other. I turn to Karl Popper (1982) and Paul Feyerabend (1993) to argue that, assuming the world is based on knowledge and realism, allowing an epistemological perspective only to be an exception, would result in a manifestation of one dominant perspective that does not allow for a “*pluralistic methodology*” (Feyerabend, 1993, 21), which is the possibility on entering an unknown space to create an open space where future solutions can take shape. I argue in favor of a pluralistic methodology and a sense for openness in scientific reasoning. In a world of high uncertainty and low empirical knowledge, tautological reasoning, as well as the acceptance of an infinite regress can be useful sources to form new perspectives on social realities.

In the second part of this chapter (Section 2.4), I summarize different definitions of risk and conclude that risk is a normative concept. My thoughts are based on literature by Terje Aven and Ortwin Renn who define risk as: “uncertainty about and severity of the events and consequences (or outcomes) of an activity with respect to something that humans value” (Aven and Renn, 2009, 6). I then define the prototype of a ‘risk entrepreneur' using Knight's idea of uncertainty, an unmeasurable entity that cannot be controlled by social behavior. A risk entrepreneur is aware of the nature of uncertainty however is able to inwardly restructure knowledge and non-knowledge of risks within social contexts, such as social institutions. A risk entrepreneur reformulates the communicative processes around how risks are perceived and how future solutions are planned and decided.

Holding an awareness of the vastness of communicative processes, I define risk as: 'uncertainty about and severity of the events and consequences (or out- comes) of an activity with respect to something that humans value. The interpretation of uncertainty and severity is a communicative social process and as such open.' Charles Perrow (1999) remarks that risks and risk communications are embedded within social power structures. To define the 'sound of risk' I have included also the existing power structures in my concept and define risk as: 'uncertainty about and severity of the events and consequences (or outcomes) of an activity with respect to something that humans value. The interpretation of uncertainty and severity is a communicative social process and as such open. The openness depends on the social power structure. The social power structure as such depends on previous decision making processes under uncertainty.'

The first part's second chapter, Section 3, narrows the scope of reflection and points towards the technologically and socially created risk of nuclear technology. I reflect on potential consequences that the existence of nuclear technology, especially nuclear weapons, can have for human life now and in the future. The existence of nuclear technology, its knowledge as well as the ability to build nuclear weapons, created a social reality in which a "nuclear Holocaust" (Jasanoff, 2006, 30) of human life on earth is possible. In this chapter I refer to Antony Giddens' book 'The Consequences of Modernity' (1990) and work by Sheila Jasanoff (2006). The aim of this chapter is to mention a utopian reality wherein it is possible to govern risks peacefully, justly, and humbly by creating new social institutions and resilient communities. Through these descriptions of possibilities like a "nuclear winter" (Giddens, 1990, 28) I want to span the scope of reflection from the case in which the risk of nuclear technology is able to destroy social life almost entirely, to a possibility wherein the existence and awareness of nuclear risk can create a new social reality which is fully prepared to solve and govern existing, as well as, new naturally and socially induced risks. The choice is ours.

In this first part, I aim to introduce the reader to the concept of risk, allowing to address risk as socially constructed as well as empirically grounded. The fear of a massive nuclear catastrophe creates a new space of uncertainty. This space of uncertainty is realistic as well as utopian, grounding reflections of how to govern risks. The sound of risk, the combination of human's realistic as well as utopian thoughts, is constantly changing. Figure 1 depicts the above summarized thoughts and emphasizes by its circular arrangement that the evaluation of risk is a self-enforcing and self-reflecting process. From my point of view there is no prevalence of one perspective. For example, the idea of a nuclear winter allows Giddens to speak about an utopian society (Giddens, 1990). On the other hand, from my understanding, social utopias led to the real scenario of

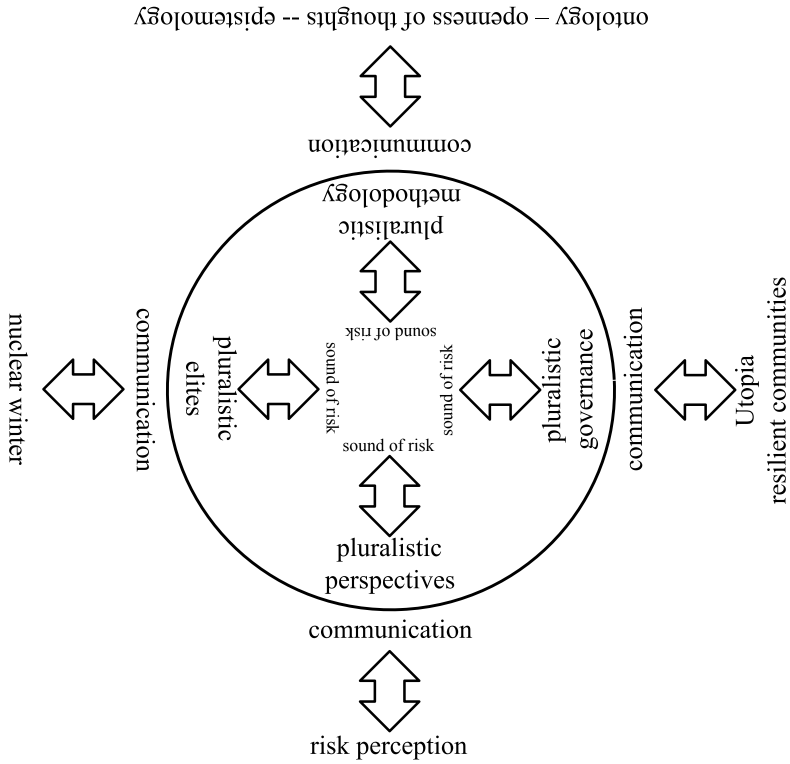

Figure 1: Summarizing the sound of risk: a multidimensional concept

world wars, as well as, to the dream of an endless, cheap, and clean source of energy in the post World War II era. I will get back to these thoughts in the introduction of the first empirical chapter (Section 6) referring to Dwight D. Eisenhower's address 'Atoms for Peace' (Eisenhower, 1953)[1] in 1953. From each perspective the concept of risk, the 'sound of risk' is real and justified, creating a space of uncertainty, the birthplace for new social realities.

[1]Document available at `http://www.eisenhower.archives.gov/all_about_ike/speeches/atoms_for_peace.pdf` (accessed October 15, 2015).

1.2. Towards a deeper understanding of nuclear risk perception

The second part, 'Towards a Deeper Understanding of Nuclear Risk Perception' shares explanations of how individuals derive their assessments and judgments of risks. Risk perception is introduced as a multidimensional concept with different facets, depending on how individuals evaluate hazards (Rohrmann and Renn, 2000). Especially in a cross-national comparative context, empirical risk perception research in social sciences varies depending on the risks under evaluation, the complexity of the design, and the sample size and quality of the data structure. This part contains a theoretical and an empirical part. The main theoretical chapter, Section 4.2, describes different approaches how risks are evaluated by individuals. The concept of heuristics is introduced to refer to a basic and intuitive approach. A risk's qualitative aspects are taken into consideration when evaluating a risk from the psychometric perspective. Research using the psychometric approach (cf. Slovic, 2000a) observed that risks, perceived as dreadful and unfamiliar, are judged as severe risks. Further important qualitative aspects of individual's risk judgment are: if a risk is taken voluntarily, if someone is involuntarily exposed to a risk, or if individuals or institutions are responsible for a risk. This chapter also discusses a risk's potential to spread in an uncontrollable way across social boundaries (Section 4.2.3 and Section 4.2.8). Risks with a high dread potential, such as nuclear power, can, in a case of an accident, affect individual or institutional actors at distant places and institutional or economic sectors that are not directly linked with that technology. In such a case, institutional or individual actors act as social amplification stations of risk (Kasperson et al., 1988). An important content in this theoretical chapter is to emphasize emotional aspects that influence individual's risk perception (Slovic et al., 2004; Loewenstein et al., 2001). Emotions seem to be an important component influencing how information related to risks is evaluated. Emotions area an important element in intuitively judging a risk activating affectively laden images. I argue that emotions are necessary to overcome socially constructed and institutionalized ignorance structures, designed to control uncertainty (Smithson, 2008).

The second part's second theoretical chapter, Section 5, systematically describes how certain individual factors are related with risk perception, specifically nuclear risk perception. This chapter provides the theoretical, empirical evidence, and analytical foundation for my personal empirical analysis on nuclear risk perception. The content is related to Renn and Rohrmann's integrative framework on empirical risk perception research (Renn and Rohrmann, 2000b, compare Section 5.6). Three questions have motivated my analyses: *(1)* How are values and socio-demographic factors shaping individual's perceptions?; *(2)* How are these factors contributing to form extreme differences on nuclear risk perception within a society?; *(3)* How do these differences differ between societies? For the first question, I have included an explanation of how values and value cluster – such as post-materialistic values – are able to influence risk perception. Even though the concept of cultural prototypes (Section 5.2.2) is not unequivocally to operationalize with the data I use I have included this approach because it allows to reflect why, due to matters of social organization, individuals approach to assess a risk can widely differ within and between societies. An important aspect to include is an individual's trust in social institutions, Section 5.2.3. Many modern and technological risks are not experienced directly, but are indirectly managed, controlled, and regulated by state authorities and institutionalized actors.

Section 5.3, describes socio-demographic factors and their relationships, aims to grasp a deeper understanding of how individual socio-demographic factors influence differences in nuclear risk perception. My first point of interest is the observed gender gap in nuclear risk perception: women express consistently higher levels of nuclear risk perception in empirical risk research. With this topic, I first consider factors such as occupational status and/or level of education as possible unobserved factors influencing the gender effect on nuclear risk perception, Section 5.3.1. Then I take a step further to reflect upon the relationship of role models, self-identity and risk perception, Section 5.3.2. Further socio-demographic aspects I consider to explain in this section are differences between younger and older individuals and how social status, political ideology, as well as locations are related to risk perception.

The following chapter summarize studies that compare risk perception cross nationally, Section 5.4. I then provide national and cross-national studies that analyze how a nuclear accident, such as the accident of Three Mile Island (1979), Chernobyl (1986), and Fukushima (2011) is affecting nuclear risk perception, Section 5.5. It can be shown that nuclear risk perception is a varying social phenomenon within any society however homogeneously distributed across societies. The studies show that the social context, such as the existing political system or the role of medias, is considered to be an influential factor that influences how individuals within a society react to a nuclear accident. The short term effect of a nuclear accident lead to substantial changes in individual's risk perception even in distant places. In the long run the level of nuclear risk perception adjusts back to pre-accident levels.

Before introducing the three empirical chapters, I summarize in Figure 2, the social components I have examined and place into relation which reflect the concept of risk perception. The core elements I am focusing on in my research are displayed in the vertical aligned factors ranging from 'heuristics' to 'social-demographic' factors that shape risk perception. In my research I do not distinguish between a hierarchical or sequential structure of this mentioned components (compare for example Loewenstein et al., 2001; Visschers and Siegrist, 2013). The elements that are horizontally ordered are steps in a risk evaluation process indicating that information processing, risk communication, and respective actions take place within a given social power structure. The arrows point in both directions to indicate that the process that forms individual risk perceptions and institutions to govern risks is a self-referential process mutually influencing each other. The source of risk, at the very left side, can be evaluated and perceived by humans if social processes have created an awareness and defined something as a risk.

In the following three empirical chapters, I focus on the vertical block in Figure 2 and test how individual factors are related to nuclear risk perception. In these chap-

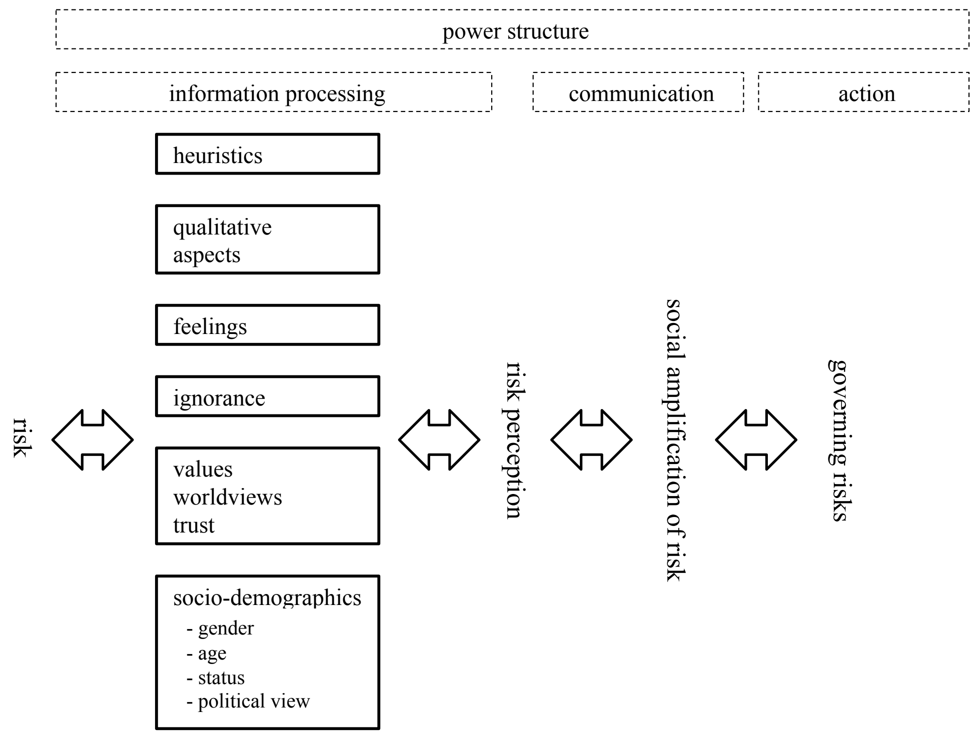

Figure 2: Overview of social factors influencing risk perception

ters I have also taken into consideration how risks are evaluated within a historically grown political power structure, which influences the evaluation process as well as how individuals are able to exchange and communicate information within a community and develop strategies to govern the risk. The three chapters are structured as separate scientific research questions and follow the structure of a scientific journal publication. All three empirical chapters use the ISSP 2010 as data source.

The first empirical chapter, Section 6, analyzes how socio-demographic factors and values are related to nuclear risk perception (compare Section 5). The analyses are performed separately for five selected countries: United States, Great Britain, France, Germany, and Japan. I use data from the ISSP 2010 conducted before the Fukushima Daiichi accident. The results show (compare Table 4) that quite similar effects are observable in all five countries: women, as well as people who have a left political orientation, express higher levels of nuclear risk perception. Older people and people with higher income express lower levels of risk concern. A positive correspondence between women and levels of education is observable in the U.S. and in France, indicating that the observed negative effect of education in this countries is driven mostly by very well educated male respondents. The development of nuclear technology and the anti-nuclear movement is summarized from a historical perspective in each country. The results allow to hypothesize that individual's nuclear risk perception indirectly influences the development of a country's nuclear project, if the political system allows civil society players to influence the political decision making processes. High levels of nuclear risk perception are a common phenomenon within all five countries – at least 39 % of all respondents perceive nuclear power plants as 'very dangerous' (compare Table 3). Furthermore, these results suggest that similar socio-demographic factors drive nuclear risk perception. Yet, national politics are differently affected by civil-society's actors, leading for example to a phase out of nuclear power in Germany and a continuity of the nuclear programme in France or Japan. Hence, it can be assumed, even though I cannot prove this statistically, that the social context in which citizen's judgment of nuclear power is expressed, directly influences how nuclear risk perception shapes social change.

The second empirical chapter, Section 7, analyses the direct effect of the Fukushima Daiichi nuclear accident on individual's nuclear risk perception. I assume that the accident on March 11, 2011 naturally divides respondents into a control and a treatment group.[2] The underlying assumption is that the accident narrows the observed gap of nuclear risk perception because people are unequally updating their views. The results show that social groups, such as men or older people, who prior to the accident expressed lower levels of nuclear risk concern, changed their views much more than individuals of similar groups who prior to the accident perceived nuclear power plants as dangerous. Heuristics, as well as emotional aspects (compare Section 4), can be used to explain the observed short term changes within the sample groups. Since individuals are social amplification stations, the results allow me to presume that sudden changes in nuclear risk perception, even if only for a short time, can put pressure on policy makers. In conclusion, I assume that after an accident people who are holding both, emotionally positive as well as negative images of nuclear power, start to question their positive images. As a result, the gap between people with lower and higher nuclear risk perception, on average, shrinks and shifts towards higher levels of nuclear concern – at least for a short period of time.

In the third empirical chapter[3], Section 8, I compare the concept of environmental concern and nuclear risk perception. The assumption is that nuclear risk perception is a specific aspect of the broader concept of environmental concern. Furthermore, that socio-demographic factors as well as individual values correlate differently with both environmental indicators. In fact, people with higher socio-economic status express higher levels of environmental concern along with lower levels of nuclear risk perception. In contrast women, compared to men, as well as people who hold post-materialistic values, show higher levels of risk perception as well as environmental concern. The results reveal that after the Fukushima Daiichi accident, respondents in the ISSP 2010 express

[2] This chapter is a co-authored work with Dr. Rudolf Farys (University of Bern) who implemented the statistical analysis and Dr. Thomas Häussler (University of Bern), who helped to structure the idea.

[3] This chapter is a translation of an already published German version (compare Vogl, 2014.)

higher levels of nuclear risk perception whereas, on average, environmental concern is not affected by the accident. For me, the question of whether nuclear risk perception is a specific aspect of environmental concern or if the concept of risk perception is a separate field within environmental sociology remains open.

I close the second part of my dissertation with a summary to explain that the theoretical concepts can be supported by my empirical findings. These are useful concepts even though an encompassing theoretical framework in environmental sociology is missing. Renn and Rohrmann's framework (2000b) is a useful approach to systematically analyze the multi-facetted nature of nuclear risk perception. The observed effects seem to be quite homogeneous across different societies. The effects differ compared to environmental indicators such as the indicator of environmental concern. Risk perception increases in case of the Fukushima Daiichi accident indicating a more evenly distributed awareness of nuclear risks among all citizens after a major nuclear accident.

1.3. The art of change

The final part of the dissertation, titled 'The Art of Change' has two chapters. In Section 9 strategies and concepts are introduced that offer the possibility of designing institutional structures able to govern risks based on a dialogical communication processes (Rosa et al., 2014). These concepts are a paradigmatic shift in decision making processes, questioning the predominant command-and-control strategy following an adaptive procedure to manage risks (Kasperson, 2013). The adaptive concept is designed first to accept each basic rationale and position's before developing possible solutions to govern risks. Involving different positions, is a necessary step to derive the best solution in the decision making process. Deliberative democratic participation combined with scientific analytical knowledge allows us to learn from experience and to pursue an adaptive management strategy based on the best available knowledge. Effective communication among all participants is undoubtedly becoming a key element towards building trust, the foundation to bridge different positions and the point of departure to adopt someone else's perspective. Effective communication also keeps everyone actors included and involved in the decision making process, even with conflicting positions. The mutual acceptance of the decision making process strengthens a community's ability to develop strategies to govern risk able to affect the community (Jasanoff, 2006).

The final chapter, Section 10, summarizes the key findings and points to the limitations of my dissertation. I am also asking the fundamental question: What lies beyond risk perception? The key findings are that nuclear risk perception is a common social phenomenon observed in all countries and as I conclude a global phenomenon. However, nuclear risk perception differs within a population due to different evaluation strategies, of which many are intuitively derived and based on emotions, challenging the assumption that risks are evaluated based on objective criteria, such as probabilities and number of fatalities. In the final chapter, I also ask if individual's nuclear risk perception bears information and could be a powerful force that can be used to transform society. I use Ulrich Beck's reflection on a "cosmopolitan moment" (Beck, 2014, 88) to argue that nuclear risk perception does carry transformational power which can evoke awareness to create social institutions able to govern risks for future generations. I further argue that the awareness of global risks, threatening the existence of humanity, opens the space for deeper reflection which can connect individuals and social groups to values able to bridge the gap of enmity. Nuclear risk perception is neither an irrational feeling nor a product of rational ignorance: it is a social phenomenon indicating that social influencers have done well in the past and could do better to govern nuclear risks in the future.

Part I. The sound of risk

2. Critical self-assessment in the philosophy of science

In the very first part of the dissertation I set out on the quest to answer the question: What is reality? To find answers to this question, I have focused on different approaches on how knowledge about reality is created? This quest – independent on how satisfying the answers turn out to be – has lead me to the more specific question of whether or not risks are real. The overall goal of this section is to provide a framework that enables the reader to understand different knowledge claims in the context of risk evaluation processes and, hence, is able to further improve decision making processes in risk assessment processes.

This section is inspired by and relies on thoughts of Eugene Rosa (2014, 14-32, see also Rosa, 1998), whose work on the meta-theoretical foundation of risk is – in my opinion – of great depth and critical ingenuity. He, as well as his work with colleagues, illuminates the boundaries of existing knowledge in various disciplines, providing a framework that categorizes as well as possible the spheres of human approaches towards our world. Rosa shapes the senses to identify different meta-theoretical perspectives and scientific paradigms in different schools of thoughts. In line with his approach I wish to follow his credo "to develop a cumulative understanding of risk"(Rosa, 1998, 16).

My argument for risk governance and future decision makers will be to create processes that shape the awareness of different knowledge claims within society. Any individual knowledge claim depends on the social context and the processes that shape individual's perception of the world. Independent of any social process, knowledge claims, I argue, are a-priori equally valid and, hence, a-priori equally an object of skepticism, vigilance, and scrutiny. An a-priori equally distributed ignorance seems to me to be an effective solution to start to learn and to listen to each other. Scientific reasoning has been influenced to a great deal by proving or rejecting knowledge claims using different methodological approaches, such as logical reasoning or empirical proves. *What if the idea of learning from each other becomes more important than proving other's knowledge as wrong?* The question then becomes: what can I learn about my reality by listening and understanding different knowledge claims. Creating fragility about a world and social processes in the world, we only barely understand or agree upon. I feel that the foundation of learning is based on the idea of identifying spaces of ignorance through allowing our own knowledge to be open to criticism. Solving complex problems in an uncertain world requires an understanding of the world beyond limited individual knowledge.

You could ask: To what degree is there an understanding of an outside world? Is there a world independent of our understanding? Does reality exist? There are two basic perspectives in the philosophy of science. One could say that these two perspectives represent two poles of knowledge claims about the world. The one pole is the ontologist or positivist school of thoughts whose most sedulous adherents believe only in a reality and truth that is independent of human perception and that can be explained, even though not perfectly. The other pole represents fearless devotees of epistemology, forming the school of thoughts of constructivism or phenomenology. In the most extreme interpretation, people believe that knowledge of an external physical world does not exist, but is constructed through experience. Knowledge, such as generalized laws, hence, is only a re-interpretation of individual experience. In the following sections I will discuss both approaches in more detail and reflect to what degree the concept of 'risk' can be embedded in either school of thoughts.

2.1. Positivistic paradigm – an ontological approach

The positivist paradigm is the most prominent approach to risk analysis (Rosa, 1998, 19). In its pure form it is in line with the scientific principles of: "consistency in internal logic, empirical support, and predictability of outcome under like conditions" (Rosa, 1998, 20). The aim of such an approach is to compare different hazards and make them accountable, and, at the end, insurable. This approach defines risk in a singular definition: risk = probability $\times$ consequences. The approach relies on both abstract and clearly defined concepts and theories, such as the axioms of probability theory or the axioms of the rational actor approach. These concepts provide clear criteria which allow for empirical testing. Technical risk analysis is based on the concept of realism. The advantage or the beauty of this approach is that risk analysis takes place in a protected space of knowledge, "within a coherent and organized framework" of a shared "semantic content": a common language of logic, mathematical precision, and mutual agreed criteria of empirical evidence (Rosa, 1998, 20). In its essence, the scientific logic of this paradigm is based on the assumption that the world and the real truth can be known, and that there are criteria that prove to what degree the truth can be studied with empirical evidence and statistical testing. If there is empirical evidence found, through various methods of observation, over a long period of time, the assumptions of the positivistic paradigm can be met, and the outside world can be tested and defined as external reality.

Rosa et al. (2014, 17-39) provide the example of gravity to support the realist view of a world independent of human observation. And still, the authors state that our understanding of the world will never be exactly as the world is, therefore always an approximation – a world of no perfect isomorphism.[4] Leaving even the infinitely small

[4] That argument allows in return to claim that socially constructed knowledge claims are never perfect but always subjective hypotheses and therefore fallible.

space for subjective interpretation on an existing external reality leads always to knowledge claims that are socially constructed – "[s]ocial construction can not be avoided" (Rosa et al., 2014, 17). However, there is also a world out there that is almost free of interpretation because brute facts have been observed by different social entities over a long period of time: the facts are ostensible and repeatable. Gravity is such an example of "pan-cultural recognition" (Rosa et al., 2014, 19). There is an intersubjective agreement of independent observers of a repeatable fact that always lead to the same result. "Such intersubjective agreement about this constraint, widely dispersed across history and collective experience, suggests that this physical feature of the world is sending compellingly similar signals to percipient observers – wherever or whenever they are. Moreover, it implies that the source of these signals is outside our own phenomenological context of interpretation" (Rosa et al., 2014, 19).

I want to point out that Rosa and colleagues use, from my point of view, a universal and neutral language to describe their view of an ontological or positivistic realism. They base their approach to prove that there is an outside world on the idea of N. Katherine Hayles (Hayles, 1995). Hayles argues that realism can be illustrated by observing limitations or constraints. That constraints are not to be influenced or changed by enabling human agency i.e. the intension of not wanting things to happen: the pencil will drop due to gravity, again and again. Humans learn that any physical feature is sending signals. Signals seem to be some sort of information that vary in their form. If they are strong, they can be interpreted as conditions of the world, independent of human activity and there are clear cases that meet the criteria of being "mind-independent" (Boghossian, 2006)[5], an indicator of an outside reality. Which also means that some signals are not clearly identified and, hence, an object of interpretation.

The shortcomings of the above mentioned positivistic paradigm have their origin in the semantic condition of a scientific and technical understanding of the world. Physical facts or signals that do not meet the criteria are not testable and, hence, exclude themselves from scientific reasoning and therefore from an accepted outside reality. An outside reality, in that sense, only exists if the signal meets the methods that are able to transform the signals into the common shared scientific languages, practices, and paradigms. The realism paradigm over-simplifies outside signals into a scientific reality to be treated as a "neutral product of science" (Rosa, 1998, 20). The narrow technical view of positivistic science provokes critique. In the case of risk identification and risk assessment, the reduction of risk into a neutral object excludes information that is for example based on values or normative judgement. The critique is that ignoring socially relevant factors leads to an ontological-bias. Risk in the positivistic tradition of scientific reasoning then is perceived as a pure ontological object independent of its context and epistemological meaning. Rosa (1998, 21) also remarks critically that if a risk's rational scientific solution is at the same time promoted as the ultimate and best solution for social reality, it does not take into consideration ethical constraints – a pitfall of naturalistic fallacy claiming that the scientific point of view is also the ethical best point of

[5] Cited in (Rosa et al., 2014, 17).

view. It is possible therefore that the technically best solution is not the socially most accepted solution.

2.2. Constructivist paradigm – an epistemological approach

Rosa et al. (2014, 15) argue that human knowledge claims always are to some degree socially shaped and an interpretation of an external reality. The authors conclude that "there can never be a *perfect isomorphism* between the world and its states and our understanding of it" (Rosa et al., 2014, 15). Scientific reasoning is never free of interpretation – the breath of uncertainty and the doubt of a misguided interpretation loom when expressing claims about the world. According to Lakatos (1999, 24), any belief has its equal right to exist next to other beliefs and interpretations. Therefore, on the other side of the demarcation line facing the "school [of] *militant positivism*" (Lakatos and Feyerabend, 1999, 24) are the schools of thoughts that are based on skepticism, cultural relativism, or rooted in the phenomenological tradition. From a meta-theoretical point of view, scientific knowledge and any perception of reality or theory claiming truth, is socially constructed and part of a belief system.

Comparing the constructivist paradigm with the positivistic paradigm, Rosa (1998, 21) points out that in the constructivist tradition the world outside is a constant process of interpreting and negotiating past actions and its possible meanings. The process of perceiving and negotiating knowledge is equivalent to the world outside, manifesting the reality at a specific time and space. Hence, "[f]or the most devoted social constructivists there is no separation between reality and our perception of reality" (Rosa, 1998, 21). From this point of view, objective reality is a cultural phenomenon, becoming real if it enters the collective consciousness or awareness of cultures and social systems, by getting a social meaning through communicative processes. Risk in this sense is not an external object, rather a social negotiation. Risks are not perceived as a constant outside object, but are continuously reshaped and defined by the ongoing negotiations between all involved social actors: "Physical risks thus have to be recognized as embedded within and shaped by social relations and the continual negotiation of our social entities" (Wynne, 1992a).[6] The nature of socially constructed risks is constantly changing, therefore, in a world of social interaction, risks are never a constant physical phenomenon.

The constructivist paradigm is not free of critique. Rosa et al. (2014, 16) mention three points of critique that are relevant in the case of risk analysis. The first point of logical critique is the tautological nature of the paradigm: "if all knowledge is socially constructed saying that the risk is a social construction is a tautology." Tautologies are statements that are true by definitions, free of falsification and, hence, not needed to be tested by empirical evidence. The constant true-nature of a tautology and its immunity of external falsification imputes information from outside world or external information

[6] Cited in (Rosa, 1998, 21)

only minor weight. From an empirical social scientist's point of view, any scientific statement needs some empirical evidence and any theory needs to be constructed that it can be falsified by empirical evidence (Popper, 1959). Rosa and colleagues criticize that because of the tautologic logic, there is no separation between constructivism, the perception of knowledge, and realism, empirical foundation of knowledge. In the end all merged into one: everything is constructed – even the construction of the constructed knowledge.

The second critique points in the same direction and criticizes the lack of sense for a need of empirical evidence. Any constructivist approach allows the possibility of neglecting an outside reality in favor of an a-priori knowledge claim. An extreme constructivist claim of reality is that since every knowledge claim is to some degree subjective, any approach to reality is as valid and as good as any other. This implies that in the end, any knowledge claim is a process of collective judgement. This equally distributed understanding of any a-priori knowledge at any time and any space does not leave much flexibility to define a criteria to chose between alternative knowledge claims about reality – say risks – leaving a gloom of indifference and apathy. Rosa (1998, 23; see also Rosa et al., 2014, 14) also remarks that if any argument is as good as any other, any combination of arguments can then be used to come up with any claim or interpretation about the world. That instrument of equal yet not testable arguments can then be used to create arguments in favor or against any existing opinion. The political consequence is that knowledge claims can be misused as an instrument to maintain or gain political power. Hence, the most powerful systems or social entities can use their power to claim and define any state of reality over any other, without worrying about or taking into consideration the consequences: "[This view] allows the powerful and unscrupulous to adopt just about any terminology – risk or otherwise – to impose their will on others with impunity" (Rosa et al., 2014, 14). The problem is, that any logical argument becomes immune to any other argument or critique if the argument is that there is no criterion to accepted any hierarchy of knowledge claims. That logic, if and only if it is used in the extreme numbed or starchy way, also stops any social process to create consensus among different views and does not permit for communicative process as a means to come to a solution about risks in our world.

The third critique of the constructivist paradigm is the logical construct of an infinite regress. If the social reality, such as a risk, is socially constructed and our understanding and knowledge claims about that reality is also socially constructed, then any assumption about reality is a construct, including the reality itself. In this case there is no outside or independent information to learn or update our understanding of the state of the world: "Our understanding of, for example, plane crashes must come, if not from something independently real, from other social constructions. [...] This reasoning sends us into an infinite regress, leading us to the absurd land of ad infinitum" (Rosa et al., 2014, 16).

To overcome the problem of equally valued knowledge claims in a world of different empirical evidence and despite the given evidence still socially constructed knowledge claims, Rosa et al. (2014, 23-32) develop an approach they call 'hierarchical epistemology'. This approach considers that any knowledge is socially constructed and even with the best methods, humans cannot generate perfect knowledge and, hence, are not able to gain an absolutely true understanding of the world. From this point of view, the world is real but the knowledge about the world is an approximation based on empirical evidence. The author's suggestion of how to perceive the level of empirical evidence about any claims about social reality, such as risks, is to construct a continuous space which can combine both, the epistemological approximation as a hierarchical continuum within an ontological world. They call this approach "hierarchical epistemology and realist ontology (HERO). Epistemological hierarchicalism does not deny the fallibility of all knowledge claims. It denies that all knowledge claims are *equally* fallible" (Rosa et al., 2014, 29). The continuum constitutes itself on the amount of mutual collective agreement or disagreement about a set of knowledge claims. In its extreme states of knowledge claims, there is on the one hand pure facts while on the other a pure interpretation.

The hierarchical distinction of the HERO approach is given by the quality of empirical evidence. The quality is defined by two criterions: ostensibility and repeatability. Ostensibility represents the degree to which an event can be identified by different individuals; for example, I can describe an object by actually observing it. Repeatability comprises all that events that can be identified in a defined space over multiple time points. The better the quality of identification – the stronger the signal an object sends – the higher the agreement on a social reality, and, hence, the closer to place an event near the realism end of the scale. The purer an object can be identified in its unique shape, the closer it becomes to an ideal type of an external fact. This are moments when the foggy dew of uncertainty shows its humility and does not cover up our knowledge of reality and its interconnectedness.

The above mentioned continuum of the HERO concept should be interpreted as a space of overlapping categories rather than a linear scale of elaborated and multi-facetted differences. Rosa (1998, 35-37) separates the space of all knowledge claims into three broader categories: a) grounded realism, b) synthetic realism, and c) social construction. Grounded realism represents the knowledge claims with high levels of empirical evidence, such as high ostensibility and high repeatability. There is low uncertainty involved and at the same time high information density about possible outcome stakes are available, i.e. high predictability. At the other end of the "realism-constructivism continuum"[7] is the space of social construction. This category contains all of the knowledge claims about the outside world that have a high level of uncertainty and predictability of possible outcomes, a space in which no information about exact consequences exists. As an example for the latter category, Rosa mentions systemic risks such as global climate change or consequences of nuclear waste disposal. As an example of grounded realism, the author refers to insurable risks like car accidents or common injuries. Synthetic realism as the middle category on the realism-constructivism continuum, contains the

[7] The author calls it continuum yet indicating that it is more of a meta-theoretical approach and in fact more research needs to prove how much of the scale can be really interpreted as a continuum, rather than a space of different categories.

knowledge claims about real brute facts, that need to be interpreted due to different claims regarding consequences and ethics. As example, the author mentions the dosage of ionizing radiation people are exposed to. Based on the criteria of ostensibility and repeatability, knowledge claims can be specified and categorized. At the same time the HERO-concept is based on the common criteria of positivistic sciences: intersubjective agreement, predictability, and the quantification in a functional form; hence, "the fundamental demands of positivistic science" (Rosa, 1998, 36). Integrating the realistic perspective allows for the possibility of ignoring that school of thoughts if the criteria of brute fact science are not met: "Indeed, [the HERO-concept] insists on the inclusion of a wide range of alternative orientations under conditions of low ostensibility and low repeatability" (Rosa, 1998, 36).

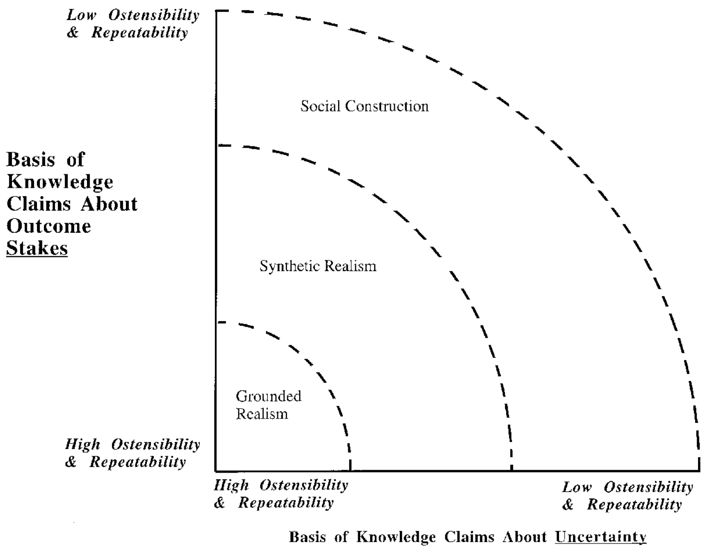

Fig. 3. The realism–constructivism continuum of knowledge claims about risk. Note: Because the diagram compresses four variables – ostensibility, repeatability, uncertainty and outcome stakes – into two dimensions, the orientation of the axes is high to low, rather than the typical orientation.

(Source: Rosa, 1998, 35, Fig. 3.)

Figure 3: Information matrix in terms of epistemological hierarchicalism.

2.3. Criticizing ideal risks – a plea for openness

I personally think Rosa's approach of hierarchical epistemology and the realism-to-constructivism continuum can be misleading and is biased towards the ideal state of predictability. The ideal of predictability is based on the assumption that the true relationship between objects of this world can be derived by more information and better models. I argue that social problems are complex social realities with low ostensibility and low repeatability; i.e. much less is known about the predictability and the causal relationship between social actions. From my point of view, and this is my critique on the bias towards a positivistic school of thoughts: the starting point should be that the state of the world is of high uncertainty and little is known about the consequences of uncertain outcomes. Hence, social constructivism is the predominant state of the social world and grounded realism the exception. In that space of uncertainty or risk we can observe areas that are of higher information density indicating higher inter-subjective agreement, such as the area of grounded realism in Figure 3. From my perspective even the world of grounded realism is still nested in the world of social constructivism, so there is no guarantee that any knowledge claim, no matter how much inter-subjective agreement exist, is free of uncertainty. More importantly the perspective of a grounded realism starts with the high preposition that all uncertainty can be explained – meaning that there is no uncertainty or openness in this world, pointing towards a deterministic world.

At this point I would like to address Rosa's critique on constructivism as explained above. I think his point of view is correct, however presents a limited view of reality, emphasizing the potential to explain social reality rather than emphasizing the complexity of social reality. He is doing right in providing a meta-theoretical approach, but it is still an approach, a guideline, not an explanation for social knowledge. Risks are complex social phenomenon. Any social understanding of any risk profits from its openness to alternative explanations, social perspectives, multiple views, and different narratives. Here, I would like to express some preliminary thoughts, while still deeply respecting the elaborated concepts presented by Rosa (1998) and Rosa et al. (2014). To support my ideas I want to refer to the work of Karl Popper (Popper, 1982), Imre Lakatos (Lakatos and Feyerabend, 1999) and Paul Feyerabend (Feyerabend, 1993).[8]

2.3.1. The open universe

In his lecture on on scientific methods, Imre Lakatos discusses in detail the demarcation problem, the question of what exactly distinguishes science from pseudoscience, meaningful science from science that is not meaningful, and intellectual honesty from intellectual dishonesty (Lakatos and Feyerabend, 1999, 20). Lakatos mentions Karl Poppers who describes the practices of intellectual dishonesty as the use of a theory that does not contain a condition under which it can be falsified: "According to Popper, intellectual dishonesty means putting forward a theory without specifying the experimental conditions under which it could be given up" (Lakatos and Feyerabend, 1999, 26). Lakatos, mentions Paul Feyerabend who argues that Popper's falsifiability criteria is not strong

[8] My critique can be criticized for its lack of logical argumentation. I think that logic forces to think in dualism, and dualism leaves not much space for creativity. What if there is a space between A and non-A? A space that consists of both and is more than both, because there is always some non-A in A and some A in non-A, that is not the intersection. Creativity, I believe, is only possible if there is an open space between any dualistic perception of reality.

enough, that it is merely "empty rhetoric to frighten school children", to use Lakatos's words. Hence, for Feyerabend there is no real criteria, but an honest view of oneself: "Feyerabend's only piece of advice is to remain faithful to yourself – to do your own thing and not let yourself be judged" (Lakatos and Feyerabend, 1999, 26). According to Lakatos, the falsification criteria is a weak criteria and can be circumvented by ad-hoc modifications and adjustments. The strongest scientific criteria on the quest to explain reality remains still someone's own judgement – a reality of modes of discourses.

After the introduction of Popper and Feyerabend by Lakatos, I want to let Popper, the teacher and Feyerabend, his student express their opinions about the world and different perceptions of reality. In his book 'The Open Universe' (Popper, 1982) Popper describes the world as a reality consisting of World 1, World 2, and World 3 objects. World 1 is the world of physical objects like trees, stones, human or animal bodies. World 2 is a world of psychological state, such as emotions, subconscious and conscious experiences, the states of the human mind, and the mind of other beings like animals. World 3 is a world of abstract things like theories, assertions, prepositions, arguments, whether they are complete or incomplete. World 3's nature is not inconsistent with itself even if all problems that have been thought or have not been thought of so far are part of it, because it is not a theory or an argument: World 3 is "[...] a class of things, a universe of discourse" (Popper, 1982, 115). It is a world that is from its very nature open, neither right nor wrong, a world of problems and their possible answers.

Following that argument of an open World 3 of discourse, for Popper the universe is open. The open universe is neither a deterministic pure causal world with infinite knowledge, nor is the open universe a probabilistic world with mere chance as the initial factor of change. The universe, in the sense of Popper, contains both and beside its deterministic and probabilistic poles, it is open: "Our universe is partly causal, partly probabilistic, and partly open: it is emergent" (Popper, 1982, 130). Popper emphasizes the importance of not ignoring the openness of World 3, the source of human creativity and of our mind's freedom, and the emergent space of future problems and solutions: "No good reason have been offered so far against the openness of our universe, or against the fact that radically new things are constantly emerging from it; and no good reasons have been offered so far that shed doubt upon human freedom and creativity, a creativity which is restricted as well as inspired by the inner structure of World 3" (Popper, 1982, 130). Nevertheless, World 3 could not exist without the ability to express thoughts and to use the beauty of the human mind, of human creativity, human reasoning and freedom. Openness allows every human being to learn, change and to transform society based on rational criticism, rather than the strength of the most powerful entities.

Popper asks whether objects are real or if there is a hierarchy of reality between the different Worlds he describes. For Popper all objects of World 1, World 2, and World 3 are equally real, arguing that there is interconnectedness between all elements in the universe: "The proposition of the truth of which I wish to defend and which seems to me to go a little beyond common sense is that not only are the physical World 1, psychological World 2 real, but so also is the abstract World 3; *real* in exactly that sense in which the physical World 1 of rocks and trees is real: the objects of World 2 and of World 3 can kick each other, as well as the physical objects of World 1; and they can also be kicked back" (Popper, 1982, 123). By 'kicking back' Popper refers to a definition by Alfred Landé (Popper, 1982, 100-101, 116-117)[9] that something is real or exists if can be kicked and in principle can kick back – if the objects of a universe interact with each other. The openness for Popper is not a question of reality or existence of objects, emotions, or ideas it is the interaction with all those elements that can be in principal real and therefore can influence the future. Language and creativity are important elements of the openness of the mind and of human freedom.

Popper also puts forward the idea of a critical rationalism and the idea that humanity can develop independently of natural selection and natural boundaries because the mind is an independent system with its own language: "[man] has produced a new world of civilization, of learning, of non-genetic growth: of growth that is not transmitted by the genetic code; of growth that is not so much on natural selection as on selection based upon rational criticism" (Popper, 1982, 123). But what is the practice of 'rational criticism' – what kind of presupposition does Popper assume if he speaks of this element in our mind? Is it a language of comparison between assumption and facts, of arguments, of plausibility, a process that guides us closer to reality and scientific truth? I will leave this question open to what Paul Feyerabend would answer.

Paul Feyerabend perceives knowledge and truth as something real and an element that exists in the world. In its very nature, knowledge is the combination of a universe of different viewpoints. In his opinion, there is no singular theory or the best way to get closer to reality or truth. What allows us to get closer to the ideal of explaining reality is the combination and the plurality of methodologies that define the universe of knowledge. Progress in human knowledge was not made by improving the best theory that existed, it was made, as Feyerabend emphasized, by contrasting: "Also, some of the most important formal properties of a theory are found by contrast, and not by analysis. A scientist who wishes to maximize the empirical content of the views he holds and who wants to understand them as clearly as he possibly can must therefore introduce other views; that is, he must adopt a *pluralistic methodology*"(Feyerabend, 1993, 21). And there exists more than just pluralistic ideas. The openness of our knowledge is the source of our creativity allowing for pluralistic views and giving space for unknown facts and its corresponding questions and possible answers. Knowledge is a social entity and in its nature is not driven by a converging mechanism that gravitates towards the truth. Knowledge is a space of alternative viewpoints that are interlinked between each other by language and methodology: "Knowledge so conceived is not a series of self-consistent theories that converges towards an ideal view; it is not a gradual approach to the truth. It is rather an ever increasing *ocean of mutually incompatible alternatives*, each single theory, each fairy-tale, each myth that is part of the collection forcing the others into greater articulation and all of them contributing, via this process of competition, to the

[9] Popper refers to Landé's work: *Foundation of Quantum Theory*, 1955 pp.3 ff., or *From Dualism to Unity in Quantum Physics*, 1960, pp.3-8.

development of our consciousness. Nothing is ever settled, no view can ever be omitted from a comprehensive account." (Feyerabend, 1993, 21).

How can one combine the ideals of scientific truth, the ideal of a critical and rational testing of theory and observations, with the idea of pluralistic ideas and methodologies? How can a scientist be a strict critic and yet hold an open mind to defend new approaches against pressure within her or his community or even within its own perception of truth and scientific dignity? For Feyerabend, the scientific human is no longer a role within a fixed context of knowledge-frames, he or she has become to be the bearer of knowledge, the keeper of the balance between different viewpoints. By being the other, by introducing and keeping the voice up for "counterinductive theories" and always pointing to the evidence that there is no theoretical approach that is able to solve the "discrepancy between theory and fact" (Feyerabend, 1993, 21). Feyerabend presents an ideal scientist as the gardener of openness rather than the defender of settled theories: "The task of the scientist, however, is no longer 'to search for the truth', or 'to praise god', or 'to systematize observations', or 'to improve predictions'. These are but side effects of an activity to which his attention is now mainly directed and which is '*to make the weaker case the stronger*' as the sophists said, *and thereby to sustain the motion of the whole*" (Feyerabend, 1993, 21).

Feyerabend encourages us to constantly look for alternative approaches for existing theoretical explanations of reality. Even the best and most common viewpoint needs to be challenged by counterintuitive approaches for it might give us the answer we are looking for to solve complex social problems. According to Feyerabend, a critical mind is trained to question by creating an awareness of underlying theoretical assumptions, of predetermined procedures, and hidden or habitual structures that might obscure the association between a-priori knowledge, observations, and association or conclusion – there might be something missing: "Usually we are not aware of [the assumptions] and we recognize their effects only when we encounter an entirely different cosmology: prejudices are found by contrast not by analysis."(Feyerabend, 1993, 22). A scientist in this sense is not only trying to improve the explanations and the knowledge we have about the existing outside world, she or he is also revealing the underlying presuppositions or patterns that form that knowledge, challenging not only the view on the world but also his or her view on him or her observing the world: "We cannot discover [the truth] from the *inside*. We need an *external* standard of criticism, we need a set of alternative assumptions or, as these assumptions will be quite general, constituting, as it were, an entire alternative world, *we need a dream-world in order to discover the features of the real world we think we inhabit* (and which may actually be just another dream-world)" (Feyerabend, 1993, 22). The ability to create an external world inside oneself, a distanced space of observations, is what Feyerabend calls a "dream-world". But the dream-world is not a world separated from processes surrounding a scientist. It is more to be understood as an invitation to think counterinductively, and to find arguments that support any counterinductive approach. It is a way to demonstrate that there are rational arguments that support different approaches and that it is likely that a best rational argument cannot be derived. Later I will use Feyerabends argument to demonstrate that an irrational approach like defending tautologies or infinite regress can be helpful to get a better feeling of how risks are perceived and constructed in a social context. At this point, I only want to be inspired by Feyerabend and his idea of an "undercover agent", who is dedicated to knowledge and humanity, but still sceptical about the social rationals behind any scientific authority: "An anarchist is like an undercover agent who plays the game of Reason in order to undercut the authority of Reason (Truth, Honesty, Justice, and so on)" (Feyerabend, 1993, 23).

It is more than just mere scientific goodwill that motivates Feyerabend's thoughts. In his heart, he is a humanitarian, and believes as does Popper in humans and in human history. As a result pluralism is not only important for scientific methodology, but also for the "humanitarian outlook" (Feyerabend, 1993, 38). Creativity and freedom of thoughts is the access point for World 3, the space for "freedom of artistic creation" (Feyerabend, 1993, 38).

An open space of creativity is not an unwanted element in human minds that should be controlled by any educational systems, rather the essential feature to finding solutions and to make changes in the world. The predominant ideal of a dualist worldview with the forced split between art and science needs be let go of in order to combine both elements imagination and reality: "Progressive educators have always tried to develop the individuality of their pupils and to bring to fruition the particular, and sometimes quite unique, talents and beliefs of a child. Such and education, however, has very often seemed to be a futile exercise in day-dreaming. For is it not necessary to prepare the young for life *as it actually is*? Does this not mean that they must learn *one particular set of views* to the exclusion of everything else? And, if a trace of their imagination is still to remain, will it not find its proper application in the arts or in a thin domain of dreams that has but little to do with the world we live in? Will this procedure not finally lead to a split between a hated reality and welcome fantasies, science and arts, careful description and unrestrained self-expression? The argument for proliferation shows that this need not happen" (Feyerabend, 1993, 38). Feyerabend defends the reflection of subjective perceptions and objective facts and laws. For him a sense of the whole universe of thoughts and knowledge, in combination with the individual experiences, ideas and beliefs, forms change and prevents any human attempts to manifest ideologies[10], and its effects on the real world: "A scientist who is interested in maximal empirical content, and who wants to understand as many aspects of his theory as possible, will adopt a pluralistic methodology, he will compare theories with other theories rather than with 'experience', 'data', or 'facts', and he will try to improve rather than discard the views

[10] I include also and additional critical remark by Feyerabend because it shows, that any given viewpoint or believe can be changed by real world entities. It is an individual decision, not always in favor of pure knowledge, that make people believe: "And we realize that proliferation may have to be enforced by non-scientific agencies whose power is sufficient to overcome the most powerful scientific institutions. Examples are the Church, the State, a political party, public discontent, or money: the best single entity to get a modern scientist away from what his 'scientific conscience' tells him to pursue is still the *dollar* (or, more recently, the Swiss franc)." (Feyerabend, 1993, 37)

that appear to lose in the competition" (Feyerabend, 1993, 33).

Feyerabend is also not only interested in the common view of our knowledge, but compares the historical perspectives and practices of the scientific system. From the historical view point, for him, the system seems to get closer and less connected. The improvements are happening within disciplines, but not in the whole universe of human knowledge. Again, he pleads for a shared practice of multiple entities or players to create and to improve knowledge: "Considering the argument in the text [for proliferation and alternative views to progress in knowledge], it is clear that the increasing separation of the history, the philosophy of science and of science itself is a disadvantage and should be terminated in the interest of all these three disciplines. Otherwise we shall get tons of minute, precise, but utterly barren results" (Feyerabend, 1993, 34, footnote 2).

So far Feyerabend is the defender of a pluralist methodology. He seems to be interested more in results and not so much in the approaches leading to results: the result demonstrates the improvement of knowledge, the openness of the system and the creativity to change human perception of the world. He says a pre-considered world of fixed ideas or fixed perceptions on how theories, methodologies and scientific rationalities should be used will not guide towards more humanity, on the contrary it will be biased and influenced by strong social forces: "Therefore, the first step in our criticism of customary concepts and customary reactions is to step outside the circle and either to invent a new conceptual system, for example a new theory, that clashes with the most carefully established observational results and confounds the most plausible theoretical principles, or to import such a system from outside science, from religion, from mythology, from the ideas of incompetents, or the ramblings of madmen. This step is, again, counterinductive. Counterinduction is both a *fact* – science could not exist without it – and a legitimate and much needed *move* in the game of science" (Feyerabend, 1993, 52-53).

2.3.2. Tautologies – sources of creativity

Rosa and colleagues (2014, 16) use a logical argument to argue against a mere constructivist perception of risks. Risks in their sense are not socially constructed. They argue that if risk is a social construction and everything is socially constructed, than a social construction is a social construction. That is a tautology. In a tautological explanation, statements about the world are not based on empirical evidence anymore and the scientific criteria of falsification is not possible anymore. Tautological explanations of the world, hence, are something to be rejected within the scientific context, because they cannot be tested. I want to argue that tautologies are not per se the dark side of scientific reasoning. Even if they do not address themselves to the empirical evidence, they might open a space of reflection precisely because they cannot be tested. The tautological space of reflection opens the opportunity to perceive a risk from different angles and different layers of consideration such as different time points, cultural views, and different power structures within a society. Different states in the world *do* exist and they send information, but it is not clear how they will be perceived by an observer or a receiving system. For instance, I can observe a car accident; I can be shocked if I am the driver; I can be entertained if I am a random person next by who likes accidents; I can be concerned or feel needed if I want to help; I can be happy that I earn money if I am the car repair service or the manager of a hospital. Risks can be understood as a normative concept. The human life can be understood as normative concept. Allowing for social constructions creates a space for creativity and openness that is a necessary and important element to understand complex social phenomena. A tautologic view on the world offers the freedom to question methodologies and its historical foundations. Carefully used it is a tool to get an understanding of the content and the background of a perspective to create human freedom, and not to blindly use methodologies to solve problems. Foremost tautologies stop feeding a hungry human-ego by wanting of stopping to ask questions only wanting to know the solution. All what humans know are different approaches for solutions, the final solution remains hidden.

The authors criticize the constructivist perception of reality. There is no continuous scale of how much a social fact is real or constructed if there is no reference point that is based in reality: "Framing the issue in this way [like a tautology and that risks are socially constructed] precludes any continuum since, by assuming the realism pole away, both poles have been fused into one" (Rosa et al., 2014, 16). My counterargument is that if we think of risks from a tautological perspective, with no defined poles does not necessarily mean that there are no poles at all. All that exist is a-priori a uniform space of equally possible situations. From my point of view, the no-difference assumption of a uniform distribution does not minimize the space of reality, but expands the space of reality. Risks in this space have a-priori the same chance to be perceived as risks as risks that are not perceived as risks. The tautologic space creates the dimensions of openness – going beyond uncertainty. Both poles have not "been fused into one" (Rosa et al., 2014, 16) as the authors claims, but by fusing they expand and create a new level or dimension of reflection. The a-priori equally densely distributed risk spaces can be influenced by different social expectations forming a changed social reality. Society and its ability to create, observe, and validate empirical and mystical evidence can form clusters of higher or lower density through a communicative process. After a certain threshold level of communicative density this social realities can be perceived as risks.[11]

This abstract view is useful to distance oneself from pre shaped and unknown expectations, expecting 'nothing' as prior state of observation. Imagine yourself for one moment in that space: a space of equal color and equally dense pressure. All movements feel the same, equally balanced noises, movements, and other sensations. Any expectation need or belief now can change that space: I want to go to work, I want to eat, I don't want to feel cold, I want to fight, I want to love, I want to learn, I want to grow, I have to be

[11] It is also possible – in this tautological space – to include another level of abstraction – such as not-perceivable natural powers – that might influence socially constructed expectations. This is only an ad hoc thought, an idea to keep alive for the future.

obedient, I must be quiet, I can play a musical instrument, I can talk, I can read, I can analyze datasets. And this is only me. In that space it does not matter, because there is only me. Imagine that many of these spaces come together and form a society with all of these expectations merge together and forming clusters of expectations. People who want to go to work, who want to eat, who want to talk, who can analyze datasets. That can lead to very dense clusters and to conflicts – or to social realities that could be perceived as risk for social entities. Now the space is not uniform with the same color and equally balanced sensations over time. The space is constantly changing because of expectations (I want, I can, I must) or because something else is entering that space with its expectations (I want, I can, I must). These expectations form realities and produce realities that can be perceived as risks. That does not necessarily mean to be the case given the – of course utopian – a-priori equally dense and balanced space of no expectations.

The idea of different clusters of density in an utopian uniform space enables us to perceive obvious risks like a car accident still as embedded in a socially constructed reality; still as something that can be non-existent in a different world of expectations. Even if we improve any technical issues to avoid car accidents, the idea of mobility is still a socially constructed feature and an observable object. To avoid car accidents, humans would have to change the idea of mobility. Human behavior and human decisions are embedded in social environments. Therefore risks are a-priori tautologic – they are embedded in a social environment and only exist because of socially created expectations.

The tautological space keeps a naive view on risks or social reality allowing for openness. It prevents risks from being minimized or improved on, such as trying to minimize the already low probability of nuclear accidents or improve the precision of already very precise nuclear weapons. The naive view does not neglect the openness of social reality and keeps the levels of uncertainty high – not allowing to be explained by scientific statements, empirical evidence, existing school of thoughts, and dominant social power structures.

If we observe a phenomenon in the social reality, we should keep in mind that there is not much knowledge available in terms of causal relationships and predictable power that explains how human attitudes and human behavior is created and interacting. We do not know much about that world we are living in and the interplay of powers. This is expressed incisively by Barrow's figure of the "degree of uncertainty" (Barrow, 1998, 67-68) (see Figure 4).

The vertical axis describes the degree of uncertainty to predict a phenomenon mathematically or with formal models. The horizontal axis describes the complexity of a phenomenon. We see that in the technical world of chemical reactions and applied sciences, there is a well defined balance of existing information and complexity so that there is a good understanding of what processes are happening and how they can be explained. In this case, there is a good understanding of the laws that cause the processes and there is enough understanding to explain the outcomes that are related to

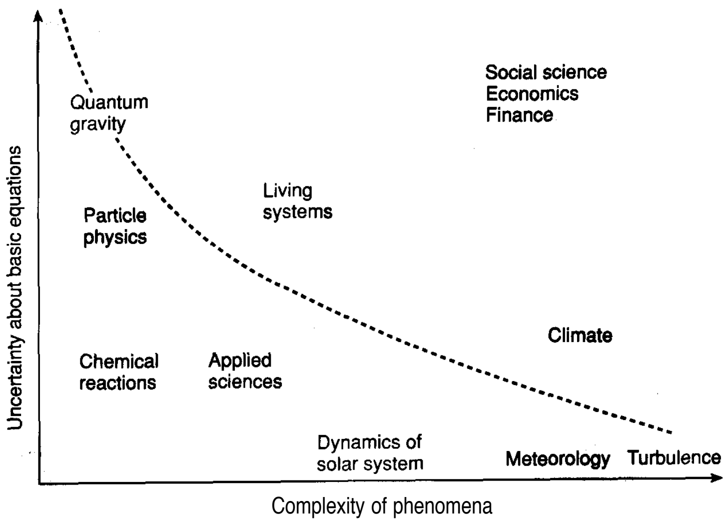

Fig. 3.2 A schematic representation of the degree of uncertainty that exists in the underlying mathematical equations describing various phenomena relative to the intrinsic complexity of the phenomena, after David Ruelle.

(Source: Barrow, 1998, 68)

Figure 4: Degree of uncertainty

the processes. With higher complexity, higher interplay, it becomes difficult to explain what can be observed, the results seems to be chaotic and uncertain, even if the laws are well known, such as in the case of highly turbulent liquids. For social world phenomena, the degree of complexity and the degree of uncertainty are very high; the combination of objects is complex and the underlying processes hard to explain in formal models; there are many explanatory factors, and less is known about the basic underlying causal processes that create changes. Hence, in the world of science, there are spaces where it is possible to predict an outcome. This ideal world of prediction is rather the world of technology and applied science than the world of social human interaction.

To support my argument for the social embeddedness of any real or constructed risk, I ask the reader to include Rosa et al.'s graphical explanation of the realism-constructivism continuum (compare Figure 3) in the upper right 'high-complexity high-uncertainty' area of Barrow's graph. As it becomes obvious, risks are still embedded in the social world. By becoming aware of the dimensions of knowledge it is obvious that it is possible to improve the existing knowledge, in the classical sense of predictable power and causal consequences. Science can construct situations that are independent of the social world. I call this, experimental knowledge gained in artificial environments which is also perceived as knowledge, even if its external validity cannot be proven. Risks are then also to be understood as the consequences of experimental knowledge put into social reality. The combination of qualities of knowledge, scientifically constructed and socially experienced knowledge, can lead to new conflicts about reality. Asking for new solutions to solve that problems. Knowledge creates new expectations.

That lack of knowledge and the limits we all face in collecting sufficient amounts of information or knowledge are actually a constant motivation force for the debate on risks within a social world. The reality is a reality of ignorance, change, uncertainty, ambiguity, complexity, and guessing combined with the mystical world of expectation, explanation, falsification, knowledge, perfection, truth, stability and lying – just to remember Feyerabend's critical or (almost polemic) remark on the "scientific conscience" and the ability to manipulate scientific knowledge using strong human powers, such as money or prestige (Feyerabend, 1993, 37). Allowing for a tautological explanation of risk prevents a critical mind of being washed away by the human powers with their sirens like alluring sound of truth any human being is embedded in its Odyssey of wisdom.

2.3.3. Skeptical arguments lost in arbitrariness

The second critique on constructivism was the critique that any skeptical argument can outnumber empirical evidence. Consequently without an external reality, there would be no criteria to chose among alternative approaches, opinions, and solutions (Rosa et al., 2014, 16). That view is plausible, but again a more constructivist approach an a-priori uniform distribution of reality, can be more helpful in finding solutions and tracing the root of real problems. The constructivist view helps to envision the real consequences of the interplay of social realities that can be harmful for the entire system. My argument against hierarchy of evidence and arguments is that risks are perceived and judged by social entities, so solutions for risks are also developed by social entities. In many questions and dealing with complex risks like war conflicts, complex technological systems such as nuclear power, or new biotechnological developments such as genetically modified organisms (GMOs), there are to some part ethical questions based on normative arguments. Focusing mainly on the predominant and available empirical evidence neglects the normative questions and the ethical component of human life on earth. Life on earth is an empirical evidence, but how those who have a life on earth are living their lives on earth is in many ways an ethical question. Empirical evidence can help to find solutions, but in the end what will lead to changes is common agreement, based on respect and the willingness for mutual solutions between living entities on this planet. Given a normative social framework, it is questionable if the best argument in case of risk assessment processes is the argument based on the strongest empirical evidence. Social risks should be judged with empirical as well as with normative evidence – a skeptical argument helps to support the latter.

2.3.4. Infinite regress

Thirdly, I refer to the critique of the infinite regress. If our knowledge is socially constructed and not based on reality, the social construction of knowledge is also socially constructed: "This reasoning sends us into an infinite regress, leading us to the absurd land of ad infinitum" (Rosa et al., 2014, 16). In its pure sense this argument is of course true. I want to invite the reader to leave the true and logical world for a moment and to take a step into this mystical "absurd land" Rosa and colleagues are mentioning. Maybe this land is not as absurd as we might first assume if we allow to disregard the logical world of scientific theory.

If risks are a social phenomenon, allowing for an infinite regress can be useful to trace back the phenomenon to the historically grown roots of the risk, such as social attitudes and behavior, technological invention, and the political decision making process. The question then is not based on the judgement whether risks are socially constructed or not, leading again to the infinite regress. Rather the question could be: how much of our understanding of a risk is socially constructed and is not constituted within the world of brute facts. I am suggesting a pseudo-constructivist view raising my voice not for an infinite regress, but for a limited infinite regress. A limited infinite regress can be perceived as a method of reasoning about a perceived reality, asking for the given and social reason that lead to the present reality. This allows a-priori to open the space of discourse for multiple interpretations. The limits are reached if the discourse entered the fields of absurdity and could not find out again, ending in frustration. As long as the social discourse is lead by the willingness to create a solution, as long as there is some evidence that either reasons are plausible, the debate is still based on a socially perceived reality and is not ending in an infinite regress.

The constructivist view helps us to free humans from ignorance and to create awareness of the unlimited limits. The problem is not how to make the world safer, but to learn when it is safe enough. To do so, we need to see the limits of our behavior and of our perceptions. Reality does not say stop, nor do scientific knowledge system say it is enough. Humans need to construct a stop, define its own boundaries and accept them as reality. The need for nuclear power is a social construct, creating its own reality. I see this as a brute fact.

I also want to warn of a naive understanding or an unwary use of empirical evidence or brute facts, such as for example "sickened or dead bodies" in nuclear accidents or plane crashes (Rosa et al., 2014, 16). The authors argue that risks are not socially constructed because there is an external reality that make us understand better of the circumstances that created a risk, such as an accident: "If a risk is socially constructed – say, the risk of airplane crash – then our understanding of that risk is a social construction. There is the risk that the plane may crash because we collectively think that it will" (Rosa et al., 2014, 16). Say for example, we talk about the risk of a beginning of a war instead of an airplane crash, then the last sentence would be: There is the risk that the war will break out because we collectively think that it will. This is realistic. There is no machine or external factor that start a war; war stems from but human decisions and expectations. Pushing my argument in favor of an infinite regress again, say the war is already happening and within this war there is an airplane crash, then the sentence would become a different meaning: There is the risk that the plane may crash because we collectively thought that it will. This statement is realistic. We collectively think that war will happen and plane crashes are an accepted consequence of a war. The airplane did not construct the reality of a war, within it can possibly crash. Humans created that real scenario, the new real world of the brut fact of an airplane crash.

Any brute fact is a real fact and creates social expectations. As a result, there is an interplay of brute facts and the social construction of expectations. The brute fact that airplanes exist may have the power to create the expectation for wars in human minds. What happens if there is an airplane, but no war? What happens if the airplane will never reveals its dangerous beauty, never crashes and never drop bombs? Who created that airplane? Who is cleaning and taking care of it? Whose dangerous tool has it become? What expectations does the existence of an airplane create? What makes an object that consists of natural materials like steal or glass, chemical substances like rubber or electronic valuable to be an object to be used to kill people? When does such an object create a possible risk?

Referring to the use of objects in a social world, the philosopher John Searle argues that agents assign functions to objects. The objects consist of natural features, but the natural features do not assign the function itself, this depends on agent's purpose: "The agents exploit the natural features of the object to achieve their purpose. [...] [The functions] only exist relative to observers or agents who assign the function" (Searle, 1998, 121). Searle concludes that functions are never observer-independent even within a given framework of causal relations. These assignment of functions to causal relations is always happening within a social context, a presupposed "teleology", as he describes the social context: "We can summarize the general point by saying that all functions are observer-relative. Functions are never observer-independent. Causation is observer-independent; what function adds to causation is normativity or teleology. More precisely, the attribution of function to causal relations situates the causal relations within a presupposed teleology" (Searle, 1998, 121). In the case of nuclear power, the causal relationship is nuclear fission, the assignment of that causal relation is to use it, for example, as a weapon or as a power resource. For the teleology of war it is a weapon for the teleology of modernity it is a power source. In both contexts, it is also both: an resource to produce weapons or a power source in weapon-systems like submarines. In the context of national states nuclear power can also function as a weapon to demonstrate a certain level of development of a country and to show its strength and independence to other countries.

Risks, I conclude, should be perceived as objects of a social context – risk are not observer-independent. That allows an observer to perceive a risk as a tautological object embedded in a world of infinite regress. A risk is perceived as a risk independent of its empirical evidence.

2.4. Defining risk

2.4.1. A first attempt to define risk

A state that is of no uncertainty, predetermined, or completely independent of human activity is a state without risk. Uncertainty in this sense is defined as an "indeterminacy between cause and effect" (Rosa et al., 2014, 21). Therefore, states of the world that are uncertain, possible, and not predetermined can be described as states of risk. Rosa et al. (2014, 21) define risk as:

"Risk is a situation or an event where something of human value (including humans themselves) is at stake and where the outcome is uncertain."

This definition contains three elements. First, reality is a state of possibilities and possible outcomes. It is not constructed as a predetermined entity. Second, reality does not follow a known mechanism or law, but there is uncertainty, uncertainty about the possible outcomes and the causal relations. There is a likelihood about the underlying mechanism of human activity but there is never certainty – leaving a space of non-knowledge. Third, if the outcome is affecting something of human value, then this is a situation that is not independent of the human world and we can talk about a risk. Possible and uncertain mechanisms, and the outcome that exist in this world and are not affecting humans, are not perceived as risks, according to this definition.

This definition is also based on the realist or ontological perception of the world: risk are real even though they always contain a subjective or epistemological element, since human's perception, cognitive ability, and knowledge are limited: "[...] risk will appear less like an objective state of the world than like a social construction" (Rosa et al., 2014, 21).

2.4.2. Personal critique on the definition of risk

To contrast this realistic few with a constructed view, I want to create possible solutions were the mechanisms of risk do not function in the expected way, but still meet the criteria of the definition.

a) Consider the world as system of space and time in which nothing exists. A system with nothing in it, where nothing can change anymore and everything is of equal shape.

b) Consider the world as system of space and time in which nothing of human value exists. No matter what mechanisms are driving the possible changes. Does this world exist in the world we are living in? It is an ethical questions to perceive this part as 'not of human value' if we want to answer the question with 'yes' or 'it depends'. If we assume that there is a non human world ($world_{non-human}$) independent of human perception and human influences there should also be a human world ($world_{human}$), dependent on human perception and of human value. Is it possible for humans to access a worldwhere nothing of human value exists? In the aggregate of all human entities taken together there are no elements that are not of human value. For each individual human entity it is also possible that something is *not* of human value.

What is of human value depends on individual perception. What is perceived as valuable can change over time and depends on the 'something' that is in the scope of perception of each individual. This 'something' is also a changing entity over time in human history. There are elements of 'something' that have been constant throughout time, and some elements are have changed, emerged, or fizzled out over time. Risk only exist in this world if humans value 'something'. Since every human is valuing 'something' differently, on the individual level, there are different shapes or densities of what is at stake. The sound of risk emerges because, on the aggregated level, there are different densities of risk, depending on what humans value and perceive as 'something' to lose or valuable to keep or expect to gain.

After reflecting the 'something' part and the 'of value' part of the definition, the physical part of the definition, I want to challenge the stochastic part of the definition – the 'uncertainty' element. The stochastic element basically means it is possible, but the given probability is unclear. It is unclear to what extend 'something' will be affected by uncertainty, and how that affects the 'of value' element. Perception of uncertainty depends on how individuals cope with randomness in the world, limited knowledge about causal mechanisms, and the openness of social life.

Risk in any world of human entities only exist if there is a possibility of change of 'something', a space of uncertain elements and of human value. A space that is free of determination and free of mere probability. If there is mere determinism, everything follows a clear causal structure and the density of risk is zero, because there is no possibility to change the mechanism, complete silence. Equally zero density of risk exists if everything is probabilistic with known probabilities, constant tones in a constant rhythm. It is a world of changes where is nothing lose or to gain, because there is no memory of the past and no expectation for the future.[12]

[12] Here is an experiment. I want to create an artificial situation in which the world can be perceived as a continuum of time in which changes happen slower than the perception of those changes – a continuum of infinitely small sequences (as the definition of a line as a sum of points). Imagine a world with uncertainty, but without perceived risks. Each sequence happens independently of the previous one but the reaction to these changes in the materialistic world happen without a lack of time. The reactions of the stochastic world and the materialistic world happen unanimous. It is like a balanced dance of reaction. In this case the mechanisms of risk lose their power and there is no perceived risk-density in the world but real change takes place. If the time between two states of the world lengthen, if the present moment becomes a longer period than the past and present decades, centuries, and millennium, the social entities will change to a social entity that contains the element of time. The elements of 'something', of 'value', and of 'uncertainty' would also become

In my opinion the above given definition of risk neglects that in the end, risk, no matter what epistemological degree the evidence has, depends on its interpretation of situations or events. The interpretation is an open and communicative process between different social actors. Here is my first updated definition:

Updated definition (1):
Risk is an interpretation of a situation or an event, whereby something of human value (including humans themselves) is at stake and where the outcome is uncertain. The interpretation of risk itself is a communicative process and as such open.

To support my argument of risk as an interpretation of reality, I will try to show the logical structure leading to the definition. I am assuming that reality is a density of information. The density is based on experienced past experiences and on future expectations. As a result, reality is an interpretation of an ontological reality. Risk is therefore is a density of information of something estimated as having value. This estimation and evaluation process is happening within a space of uncertainty. Here is an ad-hoc formal definition of the above mentioned definition:

Risk is a density of different elements: $R = X(Y) \times P(U)$, with
R = risk, X = something, Y = value, P = at stake (to a degree), U = uncertainty.

The formula can be read as: 'something' X has a certain 'value' Y. That 'something' of 'value' is 'at stake' (to a degree) P, but that 'at stake' is uncertain (to a degree) U. Risk R is a combination of two elements: an materialistic element $X(Y)$ and a stochastic element $P(U)$. The epistemological reading of the concept of risk depends on the combination rule, that rule or interpretation depends on different worldviews. From a presupposition of an uncertain world, a stochastic worldview, the definition can be interpreted as $R = U[P(X(Y))]$. This interpretation of risk can be read as: 'in an uncertain world, something of value is at stake'. We suppose there is an uncertain world and in this world something can change. Each something has a value. From a presupposition of a materialistic worldview the same elements of the definition of risk can be interpreted as $R = X[Y(P(U))]$. The reading of that interpretation is 'in a world something is of value, that something is at stake with an uncertain outcome'. We suppose there is a world of something of value and that this something of value can change due to uncertainty.

Both mentioned interpretations of risk are basically similar. I argue that if all el-

more clear because they would not change as quickly, they might be constant, they would not be touched by any short-term changes. For example, suppose humanity did not survive in the future. This would only mean that for humans the idea of life is no longer important. That might be a risk for the non human world, if humanity had been something of value for that world. The element of time is important when exploring this experimental view. Consider the possibility of a social entity that has no expectation in the future or the future has not any value. As if time itself had no value. Same with the past, no value. Or imagine the past having value, but not the future or vice versa. How does a different perceptions and value of time influence risk perception? How does it create tensions and densities of aggression in the social world? This is an open question.

ements X, Y, P, and U are the same, depending on the presupposed worldview the perception of risk R differs. From my point of view the starting point of the risk interpretation is the perception of the state of the world. In the stochastic interpretation ($R = U[P(X(Y))]$), the uncertain world is given or predetermined and this world is at risk because of the existing 'somethings' that are of value. In the materialistic interpretation ($R = X[Y(P(U))]$), the 'somethings' are given and are at risk because of inherent uncertainty in the world. In the stochastic worldview, risks can be changed if the materialistic element, the value of the 'something', changes its interpretation. In the materialistic worldview risk can be changed if the stochastic element of uncertainty is changing. The different worldviews, I argue, can lead to different social reactions and interpretations of what is perceived as a risk.

My argument for different risk densities based on different point of views relies on the assumption that in the stochastic worldview any low-probability assumption does not change the assumption of uncontrollable uncertainty. In other words, a risk remains high even if the understanding of the change of 'something' is on a higher level. Whereas in the materialistic worldview, uncertainty decreases and risk diminishes if the understanding about 'something' and its value increases. For instance, if an old nuclear power plant, with given accident probability, is replaced with a new nuclear power plant, with a lower accident probability, the risk of a nuclear accident will be less and the uncertainty of the risk shrinks. In an stochastic worldview, the change of probability does not affect the risk density because one nuclear power plant has been replaced by an newer one. The fact that the newer one has a different accident probability does not change the truth that there is still a nuclear power plant and still a risk of an accident. What constitutes a risk is the inherent uncertainty that cannot be reduced by reducing the accident probability.

Risk is a social perception or an interpretation, a density of information-units, a system of information-units. The evaluation of the 'somethings' and the valuation of 'uncertainty' are core elements in balancing a risk system. Balancing risks is a communicative process that is of constant change. If risk cannot be changed, because some parameters X, Y, P, U are not changeable, we are in a risk-trap. Say for example food is on shortage and cannot be substituted a risk emerges till the missing food will be substituted. In case of 'mind-food', such as ideologies or paradigms or places of origin, a substitution is not so easy. In such case X cannot be changed easily. The 'other' X will always be a huge risk, or not even a risk, but an element that is not part of the human reality. What if the valuation of X changes within a given social reality, say because of a changing population structure, caused by migration or a higher life-expectancy? Such shifts could lead to a self-enforcing process that increases the risk of conflict within the given risk-system. This dynamics of self-enforcing risk mechanisms are missing in Rosa et al' definition.

The element of time is also missing in Rosa et al' definition. Time-horizon, focus on past experiences or future expectations can influence risk perception of any social organism. The reaction time for change within a social system also needs to be considered.

If changes in X and reaction in Y happen simultaneously, such as an adjusted value orientation as a result of a change in the social structure, the risk-density should be the same. Too slow or too fast reactions change the existing risk-density and lead to irritations.

Since risk is not based on ontological realism but on epistemological or 'subjective' interpretation, the elements of risk perception set the dimension for risk interpretation and of how to perceive risk, and to use it as a tool for social change. I summarize my thoughts: the world is a world of possible outcomes with uncertain probabilities and consequences for humans. Humans have different interpretations of reality. This opens the space for a communicative process. This can push or influence people to go to war or become peaceful. Existing risk densities in the human world are a chance for social change.

2.4.3. Improving the definition of risk

In the next part I am going to further discuss the definition of risk, based on the concept Rosa et al. (2014, 21) present. This part is a critique on technical risk concepts that ignore the complex nature of uncertainty in their risk evaluations. The discussion will move further to a concept that has the potential to address both ideas: on one hand the idea of quantification of uncertainty with qualitative or quantitative methods, and on the other, the idea of a still unknown world with risks as an interpretation of the world. This concept focuses on the quantification of uncertainty as an approach to create states of knowledge, that are able to compare the knowledge about any risks, independently of their impact on something of human value. In this part I will mostly refer to the work of Terje Aven and his collaborative work with Ortwin Renn (Aven and Renn, 2009; Aven, 2008, 2010, 2012a; Aven et al., 2014). At the end I will add commend based on Frank H. Knight's thoughts on uncertainty (Knight, 1921).

According to Aven and Renn (2009), the existing definitions of risk can be classified into two groups. The first group is built upon technical terms combining two elements: a frequency analysis and an analysis of the consequences: risk = probability × consequences.[13] For the frequency analysis, there is usually the measure is a probability, a number between 0 and 1, indicating the chance of the occurrence of a consequence. For the consequence analysis certain terms are used to express an often undesirable outcome: losses, disutility, adverse outcomes, or adverse effects. Technically the combination of probability and consequences are often expressed as expected value or expected utility.[14]

[13] A typical definition of that concept of risk is: "Risk is the combination of probability of an event and its consequences" (Aven and Renn, 2009, 1).

[14] The expected value is expressed as the mean value $\bar{x}$ of a number of outcomes $(x_1, ..., x_n)$ and their probabilities $(p_1, ..., p_n)$: $\bar{x} = \sum x_i p_i$. The utility function does not imply a linear relationship for the expected value but assigns a specific utility function $(U(\cdot))$ to the outcome component: $\bar{u} = \sum U(x_i) p_i$ (compare: Machina, 1987, 122).

In contrast the second group of risk concepts is represented by the definition mentioned already above: “Risk is a situation or an event where something of human value (including humans themselves) is at stake and where the outcome is uncertain” (Rosa et al., 2014, 21; see also Aven and Renn, 2009, 1). This class of definitions is characterized by first a component that explicitly emphasizes the uncertain nature of the world and second a component that expresses an evaluation of the outcome.

Aven and Renn (2009) criticize both definitions and and suggest a definition that is more precise on how uncertainty is part of our knowledge system of the world. For these authors, uncertainty is an individual, knowledge based dimension, not independent of an assessor. They suggest a definition that contains following properties (Aven and Renn, 2009, 10):

1. accommodate both undesirable and desirable outcomes,
2. address uncertainties instead of probabilities and expected values,
3. is not restricted to specific consequences and quantities.

A definition of risk should contain these elements and at the same time generates enough information that a risk judgement based on the best available knowledge, qualitative and quantitative, can be guaranteed.

Technical definitions are based on probabilistic quantities and the multiplication of probabilities and consequences to derive expected values as a result of risk analysis. The technical definition misses that uncertainties can exist without being able to be expressed in terms of probabilities. This limited definition reduces the knowledge dimension of risk to only be expressed in terms of probabilities. Aven (2008) criticizes this narrow approach arguing that probabilities are only a vague measure of a risk. Uncertainties in estimation process of the true value remain, moreover estimates can be based on a selective information process: “The arbitrariness in the numbers produced could be significant, due to the uncertainties in the estimates or as a result of the uncertainty assessments being strongly dependent on the assessor” (Aven, 2008, 769). He remarks the inadequate awareness, which could be called ignorance, of the uncertainty of our knowledge of the chances and consequences of certain activities, situations or events that are perceived as risk. His argument is about the adequate interpretation of the knowledge structure, that is not appropriately pictured by probabilities, often giving the wrong impression of a very precise way to express risks: “[R]isk cannot be adequately described and evaluated simply by reference to summarizing probabilities and expected values” (Aven, 2008, 774) he argues.

It is usually the case that the scope of interpretation – the arbitrariness – is quite large, Aven continues. The urge to provide pure probabilities instead of crude entities requires a high willingness to simplify the world and to refer to strong assumptions. Simplification happens in data structure as well as on the methodological processes, leading to a bias in how to weight information or how to incorporate or ignore important factors. It seems that exact quantification is also resource demanding: “In addition, risk quantification is very resource demanding. We need to ask whether the resources are used in the best way” (Aven, 2008, 775). Given the limited resources of time and money to adequately express a precise risk picture, based on all available information and potential factors, a pure number like a probability or any risk indicator can hide the lack of knowledge or unknown or unwanted information behind the nimbus of precision and objectivity.

To bridge the gap between the need for a quantification or, if that is not possible due to the nature of the risk, a framework able to compare between different risks Aven and Renn (Aven, 2008, 775) proposed two modifications for defining risks. The first modification is to recognize that probabilities can be interpreted and expressed as subjective measures and degrees of beliefs of an assessor, and therefore are not related to the idea of an estimate of a true probability. The second modification is furthermore to emphasis the aspect of uncertainty, indicating that the interpretation of the uncertainty of a risk is a subjective judgement, based on the best available information.

The definition based on uncertainty and not on probability takes into consideration that in many cases, even with the best available information, there is still uncertainty about the occurrence and the consequences of a risk that is not be able to be explained. The definition does not preliminary lead to a normative judgement about whether this risk leads to desirable or undesirable outcomes. More so, it provides the necessary information for a judgement: “As stated earlier, the expression of uncertainty does not imply a judgement on risk acceptability or tolerability but it is the precondition that such a judgement can be made on the basis of evidence and qualified assessments rather than pure intuition or personal experience” (Aven and Renn, 2009, 7). For these authors, it is important to provide a framework that distinguishes between risk assessment, a value free approach based on knowledge, and the judgement of acceptability.

The definition Aven and Renn suggest, as a modification of Rosa’s definition (compare Rosa, 1998; Rosa et al., 2014) is: “Risk refers to uncertainty about and severity of the events and consequences (or outcomes) of an activity with respect to something that humans value” (Aven and Renn, 2009, 6).

In this definition risk is not an ontological object that exists but risk is based on the knowledge of its occurrence – it is an epistemological component. Uncertainty is also not to be seen in relation to an outcome, but uncertainty is related to the knowledge and perception of an event and its consequences. The definition defines two steps to evaluate risk: firstly, the uncertainty about an event and the consequences needs to be quantified; secondly the uncertainty needs to be evaluated in relation to the severity of an event and its consequences. The severity of an event can be evaluated by quantitative measures like money, risk indicators counting numbers of fatalities or environmental indicators, and any measure that measures the intensity or the extension as a consequence of an event, that is influencing something of human value.

The authors emphasize that their concept is based on the concept of uncertainty and not on probabilities. However, they still claim to have a comparable measure of uncertainty. Uncertainty, independent of its measure, is a construct of human imagination and not independent of an assessor's view. It is a useful concept because the choice of the measure for uncertainty or likelihood is not arbitrary, but the criteria is still based on comparability. This creates openness to acknowledge different degrees of uncertainty like known uncertainties – "we know what we do not know" – and ignorance or non-knowledge, also called unknown uncertainties – "we do not know what we do not know" (Aven and Renn, 2009, 9).

In this sense even precise measures like probabilities, likelihoods, or expected values are not perceived as given states of an objective world. All measures express an observer's degree of belief, and depend on the observer's perspective. In the subjective or Bayesian case (compare e.g., Gill, 2008; de Finetti, 2008) probabilities are subjective measures of uncertainty, based on the available information and beliefs that exist. Subjective probabilities are still an estimate, containing different levels of uncertainty. In this case there is no true objective state of the world, like in the classical interpretation of a probability as an estimate of an unknown, but fixed and true value of a world independent of an observer's interpretation: "A probability is interpreted in the classical statistical sense as the relative frequency of times the events occur if the situation analyzed were hypothetically "repeated" an infinite number of times. The underlying probability is unknown, and is estimated in the risk analysis" (Aven, 2008, 768).

A risk approach that includes risk dimensions like unknown uncertainty and state of knowledge or competence goes, beyond the standard evaluation of expected values. An appropriate outcome analysis is not easy to obtain, especially if there is no assessment culture to identify consequences that are far beyond the expected outcomes. As a first approach, a risk picture could include more critical or reflexive aspects like large uncertainties that are related to the observed phenomena, or views from experts that are challenging the given interpretations and conclusions. Aven suggests including more elements into risk assessment to critically evaluate risk. His formal notion is (2008, 774): $(I, C, I^*, C^*, U, P, K)$. I is the initiating event of risk like a hazard, C depicts the unknown consequences of that event, I^* and C^* are the corresponding estimates or predictions of the events and the consequences. The uncertainty component is U and P the assigned probabilities. Additional knowledge or background information about the model assumptions or suppositions are included in K. That wide framework opens up the space to ask critical questions about knowledge, uncertainties, and potential gaps that might lead to a false estimate of potential consequences C. The aim is to identify uncertainties and different views that might lead to consequences C that have not been taken into consideration by deriving an expected consequence $E[C]$: "This system reflects features such as the current knowledge and understanding about the underlying phenomena and the systems being studied, the complexity of technology, the level of predictability, the experts' competence, and the vulnerability of the system" (Aven, 2008, 774).

The openness to identify unexpected consequences in the real world is related to the openness in an expert's mind to identify the limits of someone's own knowledge. One way is to question the quantification mechanisms that try to identify information and create comparable results. Frank H. Knight (1921) provides a framework for how to compare different levels of knowledge, expressed in probabilities that helps to accept the limits of any estimate.

2.4.4. The risk entrepreneur – opening the unknown space

In his book 'Risk, Uncertainty and Profit' Frank H. Knight (1921) distinguishes between three types of uncertainty. The first two types are measurable types of uncertainty he calls risk. The distributions of outcome are known, either through calculation that is based on a-priori knowledge or on empirical data. The third type is a more complex type of uncertainty because it is not quantifiable. In the third case, the distribution of the outcome is not known because there is no information. Knight states that the world of knowledge is a quite static system, not the changing and unknown world that is around us: "It is a world of change in which we live, and a world of uncertainty" (Knight, 1921, 199).

The openness of the world is not reflected in what he observes in the world of scientific knowledge or in the world of true probabilities, since the aim of expert's expertise and knowledge is predictability and, hence, a static world: "We have, then, our dogma which is the presupposition of knowledge, in this form; that the world is made up of *things*, which, *under the same circumstances*, always *behave in the same way*" (Knight, 1921, 204). The complexity of the world depends on the things we choose to deal with and the given circumstances that influence the action of that things. The combined knowledge of both things and circumstances then forms the knowledge of expected consequences. Knight criticizes the accepted assumption of repeatability that things always behave in the same way when the circumstances are kept constant.

Knight furthermore questions whether the concept of a thing is logically correct because in an interconnected world, that thing is again a foundation for circumstances that influences other things; moreover, circumstances influencing that thing in the first beginning are itself composed of things. Any experience of objects in the world does not match the assumption of repeatability: "The assumption that under the same circumstances the same things behave in the same ways thus raises the single question of how far and in what sense the universe is really made up of such "things" which preserve an unvarying identity (mode of behavior)" (Knight, 1921, 205). He further challenges the scientific paradigm that even varying structures consist itself of underlying complex things that, if they are known, are itself unvarying and "ultimate" (Knight, 1921, 205). This is not what he thinks the world is made up of. The dogma of knowing cannot be based on the assumption of a closed universe in space and time. Knowledge is based on the assumption of a world that is in constant change and knowledge is only a temporary state: "*[W]orkable* knowledge of the world requires much more than the assumption that the world is made up of units which maintain an unvarying identity in time" (Knight, 1921, 205).

Knight challenges the assumption of a true probability, constant over time and given by the underlying structure of the composition of the things in the world. For him there are two types of probabilities. The first type or true probability are *a-priori* probability, which can be calculated from given knowledge and chances can be computed based on general principles about the underlying data generating process, such as a lottery in an experiment or rolling a perfect dice. The second type of probability is called statistical probability. This type is not based on given knowledge, but must be calculated inductively from a large group of cases, estimating the true parameter. In this case, the chances can only be calculated using empirical information. The empirical information can be classified and tabulated in groups of sufficient homogeneity: homogeneity being an important feature of empirical information is necessary to form relative frequencies.

The uncertainty component in Knight's concept of knowledge becomes important in situations which are not homogeneous and too unique to be comparable, hence, there is no information that can be used a-priori or empirically derived to value a judgement. In this case "[t]he conception of an objectively measurable probability or chance is simply inapplicable" (Knight, 1921, 231). To speak of an objectively correct judgement expressed by a number, like a probability, is in his sense "meaningless and fatally misleading" (Knight, 1921, 231). True uncertainty in the very strict sense is uncertainty that cannot be measured and cannot be empirically grouped or controlled and by no mean can be eliminated by social activity or socially organized behavior.

The uncertain nature of the world is an opportunity for social players to become an entrepreneur and to change the world in a certain direction: "It is this *true uncertainty* which by preventing the theoretically perfect outworking of the tendencies of competition gives the characteristic form of "enterprise" to economic organization as a whole and accounts for the peculiar income of the entrepreneur" (Knight, 1921, 232). Knight emphasizes the role of an entrepreneur as a person who starts a business idea and who profits from the potential that is inherent to the uncertain space.

At this point I want to emphasize the individualistic aspect of Knight's approach, confirming the social dimension of uncertainty as a characteristic in the world of business creation and profit seeking. An 'entrepreneur' in his sense of the word, is someone who accepts uncertainty as a social fact, senses it and tries to create social structures to integrate that uncertainty into society. Sensing and entering the open spaces in society is also a space and chance for transformation, change and creation of new knowledge about the world and its features: "It is a world of change in which we live in, and a world of uncertainty. We live only by knowing *something* about the future; while the problem of life, or of conduct at least, arise from the fact that we know so little" (Knight, 1921, 199). To accept the limits of knowledge in the first part is a prerequisite to building social institutions. Organizing social mechanisms that provide an exchange of knowledge and lead to decision making processes by mutual exchange and the willingness for consent, is an important aspect of a free society in a world with limited knowledge and changing uncertain factors: "No one denies that "man is a social animal"; and in fact society makes men far more than man make society, meaning by deliberate thinking and action. Yet I believe that individualism must be the political philosophy of intelligent and morally serious men. The choice lies between allowing people to fix the general form and terms of association by mutual consent, and having all conduct ordered by some authority, ultimately one based on a claim to a prescriptive right to power" (Knight, 1921, xlix).

I would like to include one thought Knight provides, reflecting a society and business world that can be helpful in the light of risk assessment processes. Knight mentions the entrepreneur, accepting and judging uncertainty to create new markets. He also speaks of the morality of free individuals, acting responsibly for their community or society, willing and able to transform and change previous ideas of social life, based on mutual consent. He provides an answer for why uncertainty has formed any form of social association and why uncertainty will always be the driving factor of new institutions, based on previous and given knowledge. From his point of view, uncertainty can be transformed in an objective form of knowledge, like probabilities, when the world is categorized in groups and these groups can form their own social entities. In this case, uncertainty was transformed in certainty, as the example of regulation processes show. "As we have repeatedly pointed out, an uncertainty which can by any method be reduced to an objective, quantitatively determinate probability, can be reduced to complete certainty by grouping cases. The business world has evolved several organization devices for effectuating this consolidation, with the result that when the technique of business organization is fairly developed, measurable uncertainties do not introduce into business any uncertainty whatsoever" (Knight, 1921, 231-232). If these organizations are able to control uncertainty, this is a useful practice of reducing uncertainty. The problem, in my point of view, arrises when social institutions, designed to control uncertainty, are not able to deal with uncertainty, because the nature of the 'thing' or 'something' cannot be controlled by human knowledge or human behavior. For example, if a thing is not able to distinguish between right and left it is not possible to establish a norm telling the thing to drive on the right or left side of a road.

I think that today's risk 'entrepreneur', to borrow Knight's terminology, is aware of the nature of uncertainty and feels moral responsibility. Within an open and uncertain universe, the gravity of uncertainty is pulling risk entrepreneurs towards the centers of institutionalized risk control. The entrepreneur, furthermore, is able to differentiate between all forms of certainty and uncertainty, transforming centers of risk into responsible institutions of risk-awareness, guided by the laws of uncertainty and ignorance. What are the laws of uncertainty in the sense of risk assessment? I would argue that it is the awareness of openness in any social process that is constantly challenging own perceptions or previously formed perceptions. An institutionalized open space of uncertainty takes into account that there never is such a thing as certainty. The space a risk entrepreneur creates is an institutionalized space of anarchy, creating a willingness to learn more about a risk. Aven (2008, 774) mentions an approach developed by Klinke and Renn (Klinke and Renn, 2002) that goes beyond standard interpretations of risk consequences based on monetary unities or human lives, taking into account social consequences and changes, that are beyond social accountability: “Examples of such features are temporal extension, delay effects, irreversibility and aspects of the consequences that could cause social mobilisation, i.e. violation of individual, social or cultural interests and values generating social conflicts and psychological reactions by individuals and groups who feel afflicted by the consequences” (Aven, 2008, 774).

2.4.5. Risks as a semi-normative concept

Aven and Renn (2009) try to define a risk concept that provides a fine balance between risks based on uncertainties, going beyond the limits of probabilities judgement, all the while providing a concept based on empirical evidence and on personal opinion. It is a fine line of trying to bridge the gap between measurable concepts or objectified knowledge, and perceived individual knowledge. Risk from their point of view is the combination of all dimensions of risk: “A low degree of uncertainty does not necessarily mean a low risk, or a high degree of uncertainty does not necessarily mean a high level of risk. As risk is defined as the two-dimensional combination of uncertainties and severity of consequences, any judgement about the level of risk needs to consider both dimensions simultaneously” (Aven and Renn, 2009, 8). The authors emphasize that their definition of risk does not contain an a-priori normative judgement about a state of the world. It is conceptualized to assess undesired and desired outcomes and is not restricted to certain quantities or consequences, such as cost benefit measures or numbers of fatalities. Their concept widens the narrow scope of number obsessed idealists, yet holds back those voices claiming that risk is a mere interpretation of the world: “Our proposed definition provides a conceptually consistent and practically compatible concept of risk without falling into the extreme of total subjectivism and relativism but also not pretending that risk is a measurable object similar to other physical entities” (Aven and Renn, 2009, 8).

The concept is open for an epistemological interpretation of risk, risk is what we perceive as risk – it is not a state of the world, but it still asks for a quantification or qualification judgement to assess uncertainty. Aven and Renn define risk as: “Risk refers to uncertainty about and severity of the events and consequences (or outcomes) of an activity with respect to something that humans value” (Aven and Renn, 2009, 6).

I want to update this definition and define uncertainty more precisely as an social process of communication that is as such open for interpretation and depends on many social factors. Uncertainty as well as risk is also an epistemological element – a construct.

Updated definition (2):
Risk refers to uncertainty about and severity of the events and consequences (or outcomes) of an activity with respect to something that humans value. The interpretation of uncertainty and severity is a communicative social process and as such open.

I raise my concern because I wonder how this concept will perform in an environment of social power structures with high expectations and controversy opinions, financial incentives, hierarchies, and social interests?

2.4.6. Risk perception and power

After a first definition of risk perception I wish to include less technical views of risks. For Terje Aven and Ortwin Renn "risk perception is based on personal beliefs, affects and experiences irrespective of their validity [...] [R]isk perception does not only cover perceived seriousness of risk but also acceptability of risk" (Aven and Renn, 2009, 6). Risk perception from that point of view includes a judgement about the state of the world. I refer to Sheila Jassanoff (1999) when pointing towards the political and cultural values that shape the sound of risk. The sound of risk is an ambiguous, vague, and unstandardized concept, varying across cultures and boundaries. It is concept assuming the openness of thoughts and asking for new anarchical methods. A birthplace for new perspectives, paradigms, and solutions. My aim is to show different approaches of evaluating risk and to understand different views about the past, current and future risk-state of the world. All of this information pulled together may offer hints of what needs to be taken into consideration to successfully govern global environmental problems. For a peaceful and sustainable world, as a source of life for future generations.

Risk assessment is an institutionalized social process designed to solve problems. Each process is nested within a given knowledge systems and a political power structures. Both aspects – knowledge and power – are worth considering when discussing a concept of risk.

Excursus: The sand castle
I argue that human reasoning is not a brute fact rather a complex social process. There is a different sound for any topic we talk. In fact, we can question the sound of our language that leads to making decisions. To change the existing constraints, we could add another dimension of social sound that might lead to a new type of space for decision making. One way to add a new sound element would be to distance and question who we are, the way we think and the way we talk. We could experiment with being silent and listening to other voices, perhaps in new ways.

In this excursus I want to borrow Charles Perrow's voice to let him speak about his concerns (Perrow, 1999, 2006, 2007). Picture Charles Perrow's childhood voice in an imaginary situation, when he is playing by himself in a sandbox outside his house. One day, while he is playing, an adult passes and stops to watch him trying to sculpture a complex top on his sandcastle. The adult offers to help and says 'use a bit of water that helps to form better sand'. Little Charles does so and it works. The next day, the man comes back again, this time with an oven to heat up sand. He suggests to the child: 'We use heat to melt sand and build glass. That way you can form anything you want and build the nicest sandcastles in the whole neighborhood.' Little Charles helps him to collect sand from his sandbox and watches how the adult melts sand to make glass. At the end of the day, he has a wonderful sandcastle now made of glass. The man is happy and walks away feeling satisfied with himself. The following day, the man is back again and together they create a second castle. This time little Charles cuts himself on a sharp edge of the castle, his finger bleeding. The adult calms him with a candy and stops the bleeding with a band-aid. Now Charles has two sand transformed glass-castles in his sandbox. Some of his sand is gone, but they look so wonderful and are great to play with, and are an endless source of fun. He watches them carefully while playing with other children. The man does not return and, after a few weeks, Charles forgets about him. The wound, healed leaves a little scar on his finger. Every evening when he goes to bed he prays that the next day will be as good as the day he had today. Every time he folds his hand to pray, he sees the scar.

Over time, he starts to worry about something happening to the glass-castles. What if it breaks, leaving many sharp edges? I could cut myself. He calms his fear by counting all days he has been playing in the sandbox with his glass-castles, without anything unusual happening. Happy with his answer, he sleeps deeply. The next evening, while praying, he sees the scar and asks himself what would happen if the castle broke into tiny bits of pieces? He calms himself by reasoning, even if it does breaks apart, by carefully cleaning the sand of all sharp pieces, he will not get hurt. Happy with his answer he falls asleep. The next evening he asks himself about the cleaning, what if I cannot find all pieces and some are left in the sandbox? Even if I am cleaning carefully, even more carefully that when I clean the kitchen, the way Mom asks me to do? He calms himself by realizing that the sandbox is big enough that he could play in only one half of the sandbox. This time he does not go back to sleep, but asks himself what if the other glass-castle in the second half of the sandbox also breaks and what if I cannot clean that part? Then he remembers that a neighbor's friend also has a sandbox and that he could ask his parents to build a new sandbox as a present for him. Satisfied with his answers, he goes back to sleep.

Little Charles forgets the scar for a while and nothing happens. He plays in his sandbox, watching nature; he likes to watch birds and he dreams of flying like a bird. He imagines how he would take his glass-castles up in the air and take them anywhere he wanted to. In the evening, while praying he imagines birds flying with glass-castles above him and he sees himself as one of the birds. Then he sees the scar and this reminds him of the sharpness of glass. He asks himself, what if there are big birds flying with big glass-castles above me and what if they drop them on my house? How can I go to my sandbox to play with my glass-castles in the sandbox, what if there are tiny sharp pieces of glass everywhere? I would cut myself again and again and I could not walk or play anymore. It takes little Charles a while to calm down, by constantly counting the days nothing has happened in the past. The next day, while playing in his sandbox he has mixed feelings when being near the glass-castles, but he cannot get rid of them. He feels afraid of a giant bird that might take them up in the air, drop them somewhere, and harm him or other people. He does not what to do. After a while, he wonders what if the sandbox is the only place he can go to, or what if the world is a sandbox and he cannot go to another sandbox to play in. This evening, while praying he thinks that he doesn't want the glass-castles anymore. He doesn't wont them to break to hurt him. He doesn't want them to be dropped somewhere hurting someone else. Little Charles Perrow grew up and he became a professor at Yale University. That is how the excursus ends.

The intention of Charles Perrow's work seems to be a constant questioning of existing views of realty. Perrow is pointing into directions that might not previously been taken into consideration. For him, experts use methods to come to conclusions. Today's methods are based on accountability and empirical facts. Experts are professionals trained to use their methods and feed them with created empirical evidence. Empirical evidence such as "toting up the deaths" is created to match the methods (Perrow, 1999, 322).

Perrow's thoughts are circulating around technologies that are like the giant flying glass-castles that could break in the future creating catastrophic damages to humanity. He criticizes people who only look back saying that nothing has happened so far, because these people claim, that according to the methods used and the existing data, these technologies are safe: "A working definition of an expert is a person who can solve a problem faster or better than others, but who runs a higher risk than others of posing the wrong problem. By virtue of his or her expert methods, the problem is redefined to suit the methods. Because you can count, and because we have data on deaths, the choice is defined as a problem of toting up known figures. I define the problem as one of potential consequences, not observed ones" (Perrow, 1999, 322-323). By pointing his finger, maybe the one with the little scar, above our heads in the sky, Perrow is envisaging a potential situation that does not yet exist, an unpredictable consequence of today's practices and methods. He also emphasizes not ignoring potential threats or risks that are easily forgotten because they have not yet happened, and my only occur once. Such is the threat of a potential nuclear war: "Your concern with power lawnmowers or automobiles, where we have good accident statistics, may save more people from injury and death, than my concern with nuclear war, which happened only once and has very low chances of happening again" (Perrow, 1999, 323).

For me, the nuclear holocaust is an important element to be aware of because this is a realistic and plausible end to humanity. A social reality that happens only once, the impossibility, the black swan of empirical evidence (Aven, 2013; Taleb, 2010). Nuclear war is entirely human made and created by existing worldviews, knowledge, and human technology. It could be stopped or started through human decisions. Not a collective decision. For Charles Perrow, the debate about risk and how to deal best with risks is not a matter of the existing risk culture in society, but a matter of the existing power structure within that society (Perrow, 2006).

Questioning the way risks are defined and assessed in society is also a way to question the existing power structures. Giving voice to critics who question the power structure in society could also be a chance to reduce the vulnerability of the social system the risks are created in. Giving voice opens the space for different opinions, independent of how they are embedded in the given power structure in society. The debate about risk can help to open those dense power structures to form a new space of more interconnectedness and more ways to exchange and discuss in society: “The way we have formatted the discussion of risk in our popular culture and academic literature also tends to avoid the issue of power. Everything is connected in our world, we say, and that is true. But the most important thing about the connectedness is often overlooked: most of it involves dependencies rather than interdependencies” (Perrow, 2006, 53). If the social system is more interdependent no dominant structure could be formed and kept stable because “[i]nterdependency means reciprocity, mutual affect and mutual adjustments. It also means choice, which is achieved through redundancies, where, for example, a firm has many suppliers to choose from and many customers to sell to” (Perrow, 2006, 53).

The elements to discuss from Perrow’s point of view are then to question the given and previous power structures that created a risk, to discuss the relation between dependencies and interdependencies within a society which then will lead to the question of who was involved in the decision making process and what kind of options did exist to choose from. Analyzing the catastrophic consequences of nuclear technology, Perrow comes to the conclusion of abandoning nuclear power and nuclear weapons (Perrow, 1999, 347).

The option to abandon existing technologies is, from my point of view, an important aspect in governing risks, that has not yet been effectively realized in human history. The term risk, then takes on a different meaning. Risk then defines social practices and social spaces that are too dangerous to human life. A risk for humanity, not only, as the above discussed definition by Rosa et al. (2014) claims, ‘something of human value’. In this sense I am questioning the definition of risk again. The interpretation of uncertainty and severity is based on the existing social power structure of decision making. Risk decisions are also made to maintain the existing social power structure – a structure that as such is created by past decision making processes in an uncertain world.

Updated definition (3):
Risk refers to uncertainty about and severity of the events and consequences (or outcomes) of an activity with respect to something that humans value. The interpretation of uncertainty and severity is a communicative social process and as such open. The openness depends on the social power structure. The social power structure as such depends on previous decision making processes under uncertainty.

According to this definition, risks are socially constructed and can be reversed by social processes. How humans deal with their risk is an open process based on human decisions. Risks as such are part of an infinite social regress, not to be stopped and not to be avoided, all the while, not able to be fully explained by a model or a social theory. Risk is open by nature. Not because of its objective nature but because of its social interpretation. Therefore humans cannot control risk, but can learn to change them. This open space surrounding risks is, in my opinion, the ‘sound of risk’. A sound that can transform society because it has the power to influence decision making processes within the existing power structure.

3. Risk as a consequence of modernity

3.1. Anthony Giddens' modernity

For the following chapter of my dissertation it does not matter if risks are real or if they are socially constructed, nor if they even exist. What matters is that there are 'things' out there in the world that have consequences. Some consequences are maybe not desired by the next generation of humans on earth. The next generation does not only inherit our knowledge, it also inherits our 'things', along with the actual and potential consequences of that knowledge and that things. An obvious question is: What are potential consequences for future generations and what are the things that lead to that consequences? To focus on the main topic of my work a following question then is: How is this question related to nuclear technology? My answer is: that thing what we want to catch by thoughts and word is called 'nuclear totalitarianism.' It is that a technology can lead to a Holocaust[15], a mass extermination of social life at certain areas of this planet, including the entire planet itself. And it is not that technological systems are wanting to do that. But technological systems are part of human life and humans have the potential or want it to happen.

The question therefore is: How to make humans not to want a thing, such as the nuclear Holocaust, to happen? This discussion, from a scientific point of discussion, will not lead to a conclusive end. The aim is to focus on the consequences and not to make them happen in the future; not even trying to answer the question what the true nature of risk really is. Not today's consequences but consequences for future generations. And consequences not for the next generation, but for future future generations. Generations that have a different social order, different boundaries, different abilities than we have today. Generations that will bear the consequences of today's decision making processes.

From a future observer's perspective, it does not matter who is today's risk taker and risk bearer, nor what is the risk assessment methods that exists today are. Future generations will find methods to deal with today's consequences. What we can do today is to start to play 'future generation'. We could skip some parts of history and make the nuclear Holocaust not happen. A dissertation in the future then would also not be written to discuss risk and its consequences to improve existing risk assessment methods. The dissertation then would be the story of why the Holocaust did not happen and why humans are able to use knowledge and to understand the consequences of knowledge. It

[15] Middle English : from Old French holocauste, via late Latin from Greek holokauston, from holos 'whole' + kaustos 'burned'.

would be a story why war will never happen again. Why war was abandoned from human reality, not a technology which was abandoned, but a human practice that became no longer relevant to human reality.[16]

3.1.1. Risk and danger

Anthony Giddens is a philosopher who tries to encompass the above mentioned dimensions of peace, no totalitarianism or nuclear Holocaust, in a world of risk. He uses the term of risk but is not focussing on the term of risk, basically leaving the term risk its openness.

Think of an ice age, the ice age of human created risk to be more precise. Today's world is covered within a thick ice shield. The ice shield of modernity, of the 20th century, the century of totalitarianism and world wars. There are two human made risks which have created this ice age: the language of war and the knowledge to use the tools of war. The mental constructions of 'enemy' has produced a mental ice shield in human minds. It has also produced the tools of war to attack an enemy, sealing the mental ice shield with an technological shield of weaponry of mass destruction. The mental ice shield has created territories that can be delineated as enemy territories. Assigning unknown humans as risk. Anthony Giddens (1990) calls the ice age 'modernity'. The ice shield he calls the idea of an 'nuclear Holocaust'. What could melt the ice is what he calls an 'ethic of planetary care' or 'Utopia'.

Giddens sees a direct connection between the logic of modernity and the logic of totalitarianism. From his point of view, "[t]otalitarianism and modernity are not just contingently, but inherently, connected" (Giddens, 1990, 172). The idea of superior national ideologies combined with national knowledge has led to an unchained race in technological domination and hegemony. Nuclear power is the outstanding example of the logic of dominance through technological knowledge. Scientific knowledge in this case is a weapon, used to create real physical weapons to harm other people. The combination of science and weaponry technology, as Giddens points out, will therefore again and again produce technologies that are as much of a threat as nuclear power (Giddens, 1990, 172-173). Risks in this sense are not mere factors to analyze and to measure, risks have a history and a story to tell. To control risks, one needs to understand the forces that created the risks. To solve risks, there is no one-dimensional technological solution, but only a complex social solution.

Risk in the sense of Giddens' notion is a term that evolved with the meaning of chance. Chance and risk emerged into modern thinking when traditional and religious knowledge claims about the world were put into question: "[t]he concept of risk replaces

[16] I deeply hope that in the future everybody will be able to write a dissertation or a masterpiece, not a dissertation anymore as we understand today. A dissertation based on the language of peace, justice, and sustainability and not on the language of war, ignorance, and success.

that of *fortuna*", as Giddens states (1990, 34). Risk in this sense can be perceived as a symbol of a paradigmatic shift into a new area. Where 'fortuna' represents the old religious point of view of a given reality by a divineness; risk represents the perception of determination and contingency of the new area of modernity. The concept of risk is also a symbol for trust in modern thinking, new forms of social institutions, and social systems. It is also part of a general awareness that human activity is the source of new social and technological processes. And these activities are based on human moral beliefs, the knowledge of natural causes, and an open character of the world. Risk opens the scope for new chances independent of given moral and mental concepts within a deterministic religious cosmology (Giddens, 1990, 34).

Unlike the definitions of risk discussed in previous chapters, Giddens distinguishes between risk and danger, even if he mentions that it is a fine difference (Giddens, 1990, 34). Danger is a state of the world that is a threat to a desired outcome. Danger can be out of the scope of human awareness. Risks, in contrast, are within human awareness. Taking calculated risks and choosing an action includes an awareness of alternative actions and its expected outcomes and potential threats to that outcomes. Human reasoning is not free of ignorance and the open character, the contingency, of the outside world leaves space for unaware and threatening moments that can affect desired human action. Humans, in this case, are not aware of the danger. For Giddens human life is still based on the awareness or unawareness of danger – not of risk. The concepts of trust and risk are used to control the dangerous nature of life: "[r]isk and trust intertwine, trust normally serving to reduce or minimize the dangers to which particular types of activity are subject." He continues to also mention the context in which risks and trust environments are embedded. "What is seen as "acceptable" risk – the minimising of danger – varies in different contexts, but is usually central in sustaining trust", Giddens explains (1990, 35). Risk in this notion can be interpreted as a social construct, creating and sustaining trust, depending on the context and the awareness of danger.

Modernity is characterized by the emergence of new social institutions and a new dynamic within that social institutions. The essential core element is the nation-state as new social institutions and expert systems like scientific knowledge as driver of rapid technological and ideological change within and across the new social institutions.

The dynamic of the new institutions (Giddens, 1990, 6) lead to an institutionalized, organized environment of changes. According to Giddens the main driver has been technological change. The pace and scope of institutionalized changes developed into dimensions of near or global reach. Modern institutions, like the nation-state, have an intrinsic nature and are able to combine and organize social life more efficient. Capitalism, as Giddens explains, the accumulation of capital within competitive marked environments and industrialism as a mechanism of nature transformation in human build environments created also new environments of institutionalized risks, or unintended consequences of modernity. According to Giddens modernity developed its dynamic nature because of a transformation of time and space from local time-space units or communities into larger social system of same time-space orientation. The invention of a mechanical clock and a uniform calendar helped to create new spaces of social life. The local place lost its local time and rhythm, the new space got its new time, or as Giddens points out “empty” time dimensions (Giddens, 1990, 17). Social institutions could use that time to define time zones such as the social space of a working day. In the same way new “empty” spaces emerged (Giddens, 1990, 19), independent of the local environment, allowing them to transform, such as new market places or parts of the world to explore. The local space got transformed by social activities and decisions distant from them.

Further increased relation to social others, distant from given local space, is also a mechanism in modernity, leading to new institutions and new social systems. “The advent of modernity increasingly tears space away from place by fostering relations between “absent” others, locationally distant from any given situation of face-to-face interaction” (Giddens, 1990, 18). The “lifting out” of social interactions and relations from local environments to an “indefinite” or almost undefined space is termed by Giddens as “disembedding” (Giddens, 1990, 21). Giddens explains: “The image evoked by disembedding is better able to capture the shifting alignments of time and space which are of elementary importance for social change in general and for the nature of modernity in particular” (Giddens, 1990, 22). Disembedded social time and space systems create a new openness of the world, an openness to abstract knowledge, mental spaces, point of views, new ideas, as well as an openness to organize social life.

The disembedding of social systems formed new social forms of interaction and expertise, called expert systems, individuals mutually rely on: “By expert systems I mean systems of technical accomplishment of professional expertise that organise large areas of the material and social environments in which we live today” (Giddens, 1990, 27). According to Giddens, expert systems are spaces of social knowledge and organization beyond individual control that create the whole social system. Individuals accept their lack of knowledge of the world and trust the professional expertise of expert systems, like car and airplane transportation, construction of buildings, finance technology, energy supply or health institutions and medical doctors. Expert systems, such as scientific disciplines, define universal mechanisms and codes independent of the local context. In that sense expert systems become universal and independent systems with own time-space dimensions, but also depend on the acceptance or trust of those absent of the knowledge or information. Giddens concludes: “An expert system disembeds in the same way as symbolic tokens, by providing “guarantees” of expectations across distanciated time-space. This “stretching” of social systems is achieved via the impersonal nature of tests applied to evaluate technical knowledge and by public critique (upon which the production of technical knowledge is based), used to control its form” (Giddens, 1990, 28).

Aside from the separation of time and space on one hand and the disembedding of social systems on the other, the “*reflexive ordering and reordering* of social relations” (Giddens, 1990, 17) explains the dynamism of modernity. The ordering of social relations is mostly related to an constant change of knowledge and updating of information within the social systems that results in reordering of interactions in social, political, or economical relations. The constant transformation and dynamic also identifies the own limits of institutions and expert systems, creating new paradox or new pressure on knowledge, action, and social organization, especially if these organizations rely on trust of individual people. Confidence and faith are still important elements for building trust in expert systems: "An element of Simmel's "weak inductive knowledge" is no doubt very often present in the confidence which lay actors sustain in expert systems. There is a pragmatic element in "faith," based upon the experience that such systems generally work as they are supposed to do. In addition there are often regulatory agencies over and above professional associations designed to protect the consumers of expert systems – bodies which licence machines, keep a watch over the standard aircraft manufacturer, and so forth" (Giddens, 1990, 29).

Risks in Giddens description of modernity arise as the risks show their global reach and their high consequences. Modernity itself became a character of a "runaway" world because in the reflexive world of time space "distanciation" no individual is able to be taken into responsibility or is able to provide a solution to help (Giddens, 1990, 131). The main characteristic of modern risks is the fact that, beside best human action and knowledge, there is no solution to eliminate the possibility of potential failures – the danger still exists. In the case of great systemic risk like a nuclear war, an accident or global climate change "... *fortuna* tends to return" (Giddens, 1990, 111), humans have no answer but to turn again towards faith.

Giddens identifies seven characteristics of modern risks and presents a risk profile of modernity (Giddens, 1990, 124-125):

1. "*Globalisation of risk* in the sense of *intensity*: for example nuclear war can threaten the survival of humanity.
2. *Globalisation of risk* in the sense of *expanding number of contingent events* which affect everyone or at least large numbers of people on the planet: for example, changes of the global division of labour.
3. Risk stemming from the *created environment*, or *socialised nature*: the infusion of human knowledge into the material environment.
4. The development of *institutionalized risk environment* affecting the life-chances of millions: for example, investment markets.
5. *Awareness of risk* as *risk*: the "knowledge gaps" in risks cannot be converted into "certainties" by religious or magical knowledge.
6. The *well-distributed awareness of risk*: many of the dangers we face collectively are known to wide publics.
7. *Awareness of the limitations of expertise*: no expert system can be wholly expert in terms of the consequences of the adoption of expert principles."

Giddens' risk profile can be separated into two sections. The first part of the profile (characteristics 1 – 4) describe the scope and intensity of potential risks, like nuclear war and the collapse of investment markets. He claims that humans created and institutionalized risk environments that are of global dimension in terms of interaction, like changes in the global division of labor, or in terms of threat potential for humanity, such as elimination of humanity in case of a nuclear war. The second part of the profile (characteristics 5 – 7) describe the social awareness or perception of today's risks. Risks in that sense are knowledge gaps that are known or scientifically proofed and known to the wide public. Giddens not only emphasizes laypeople's awareness, but points out that the expert systems as such are aware of their lack of knowledge and the potential knowledge gaps or uncertainties. In this sense it becomes obvious why Giddens speaks of risks as "manufactured uncertainties," created by human activities and decisions (Rosa et al., 2014, 86; see also Giddens, 2002, 26). Personally, a more suitable term is what Giddens (1990, 35) calls "environments of risks," because it indicates the social and the spacial dimension of modern risks. It also indicates that the awareness of risks creates new social systems: "Risk is not just a matter of individual action. There are "environments of risk" that collectively affect large masses of individuals – in some instances, potentially everyone on the face of the earth, as in the case of the risk of ecological disasters or nuclear war" (Giddens, 1990, 35).

The idea of a nuclear war, as an example for an environment of risk, also wipes out the idea of real security: "We may define "security" as a situation in which a specific set of dangers is counteracted or minimised. The experience of security usually rests upon a balance of trust and acceptable risk. In both its factual and its experiential sense, security may refer to large aggregates or collectivities of people – up to and including global security – or to individuals" (Giddens, 1990, 35-36). Security is socially created, based on the level of trust and the related awareness or accepted risks within a system. Security requires dangers and means or actions to minimize the detected dangers. In the context of intrinsic modern institutions, like the nation-state the need for security can also produce new risks and conflicts. The distant other can become the enemy. According to Giddens, ontological security is an emotional, an unconscious phenomenon of humans "being-in-the-world" (Giddens, 1990, 92). In this context he refers to basic trust as the main bearer of an balanced emotional state, as the source of security. If an individual or a society is lacking a sense of trust, not security, then dread is the dominant feeling and rising its voice to demand security: "If basic trust is not developed or its inherent ambivalence not contained, the outcome is persistent existential anxiety. In its most profound sense, the antithesis of trust is thus a state of mind which could best be summed up as existential *angst* or *dread*" (Giddens, 1990, 100).

3.1.2. A nuclear winter

After introducing Giddens' ideas of risk, danger, expert systems, modern institutions, time and space, as well as trust and security, I want to return to the risk of totalitarianism as a consequence of modernity.

The twentieth-century history has proven, that the beauties of modernity like technological development, scientific knowledge, free markets, and nation-states based on democratic constitutions have been more of an illusion than the emergence of the new creativity and liberty. The "dark sides" (Giddens, 1990, 9) of modernity, as Giddens critically remarks, are manifested in the military power and the industrialization of war, as well as the surveillance and social supervision of citizens. The idea of a nation-state, as an institution of security created a new environment of risk, which has become known as totalitarianism: "In the wake of the rise of fascism, the Holocaust, Stalinism, and other episodes of twentieth-century history, we can see that totalitarian possibilities are contained within the institutional parameters of modernity rather than being foreclosed by them. Totalitarianism is distinct from traditional despotism, but is all the more frightening as a result. Totalitarian rule connects political, military, and ideological power in more concentrated form than was ever possible before the emergence of modern nation-states" (Giddens, 1990, 8). He explains that prior to World War I a bureaucratic social organization, based on the Weberian idea of rationalization of human activities, within a military regime of power could connect with the innovative forces of industrialism to create new visions and realities of mass destruction and ideological domination. The ideas of two blocks on the planet and its nuclear arm race as resent result of global warfare in human history make Giddens come to a pessimistic conclusion about the state of the world: "The world we live today is a fraught and dangerous one" (Giddens, 1990, 10).

I want to expand further on Giddens thoughts on the nuclear danger. For Giddens, the danger of the modern world lies in the destructive potential of its military institutions, including the scenario of a nuclear conflict: "We live today in a global military order in which, as a result of the industrialisation of war, the scale of the destructive power of the weaponry now diffused across the world is massively greater than has ever existed before. The possibility of nuclear conflict poses dangers no previous generations have had to face" (Giddens, 1990, 10). War in that sense cannot be perceived as a solution to solve risks anymore, because the potential threat of a global nuclear war does remain. Unlike other risks the nuclear winter or nuclear Holocaust – as Giddens calls a global nuclear war and its consequences for humanity – is a hypothetical scenario, created and implemented by human institutions. The means for that scenario are produced and designed by organized human knowledge; it is a desired scenario, an ideological and materialistic manifestation of the industrialization of war. Any real nuclear winter would not be survived or could not be assessed by any institutions or social systems that build the bombs: "[...] the risks of a nuclear war as such, are controversial in terms of any assessment that might be made of strict probabilities. We can never be sure that deterrence "works," short of the actual occurrence of a nuclear combat – which shows that it does not; the hypothesis of a nuclear winter will remain just that unless its actual occurrence makes any such considerations subsequently, since both are important in relation to the experience and perception of risk" (Giddens, 1990, 28). The ideology of modernity with its runaway dynamic created socially organized knowledge structures and ideologies that are able to eliminate humanity.

The runaway dynamic of modernity created an awareness of risks and dangers, as Giddens claims. Pre-modern perception of danger perceived threats as an external effect of nature. The new knowledge structures and institutionalizing of responsibility and the expectation to control threats created a new awareness of external threats, such as ecological threats. Potential dangers are known and transformed into risks by knowledge: "Ecological threats are the outcome of socially organized knowledge, mediated by the impact of industrialism upon the material environment" (Giddens, 1990, 10). I would go even further and replace the term 'ecological' and 'material' with 'social' and 'human' to emphasize that the human environment with the waste source of wisdom, emotions and creativity, set into an environment of organized knowledge dynamics and dynamics of industrialization, can create social threats. Social threats can pass the extreme ends or boundaries of its own social space. This process is creating, for example, a nuclear war for humanity as a new environment of risk.

The world has become a world of "potential global catastrophes" (Giddens, 1990, 25) with risk, such as nuclear accidents, that have low-probabilities and high-consequences. Giddens clearly points out that existing human knowledge, such as the knowledge to build a nuclear bomb, cannot be eliminated and completely controlled in the future. Thus risks can only be minimized, never controlled: "Low-probability high consequence risks will not disappear in a modern world, although in an optimal scenario they could be minimised. Thus, were it to be the case that all existing nuclear weapons were done away with, no other weapons of comparable destructive force were invented, and no comparably catastrophic disturbances of socialised nature were to loom, a profile of global danger would still exist. For if it is accepted that the eradication of established technical knowledge could not be achieved, nuclear weaponry could be reconstructed at any point" (Giddens, 1990, 133). The most obvious point is that since the combination of science and military power has created weapons of high threat potential, future generations can invent new technologies as deadly or as catastrophic as nuclear power (Giddens, 1990, 172). I argue that new utopian spaces for human reasoning and action need to be created to form a global human risk perception, with the awareness of the deadly potential of human creativity and reasoning. In a world with no empty spots anymore, there is a need for a new "empty space" (Giddens, 1990, 19).

3.1.3. Unreal threats and empty spaces

The catastrophic potential of modernity's dangers creates a new perception beyond technical assessments and organized knowledge systems. In its core, the threat of a nuclear war is not perceived as real for it is beyond accountability. It also creates a permanent sense of uncertainty for human life, questioning modern institutions and believe systems like the idea of rational control of human life. Giddens states: "The greater the danger, measured not in terms of probability of occurrence but in terms of its generalised threat to human life, the more thoroughly counterfactual it is. The risks involved are necessarily "unreal," because we could only have clear demonstration of them if events occurred that are too terrible to contemplate. Relatively small-scale events, such as the dropping of atomic bombs on Hiroshima and Nagasaki or the accidents at Three Mile Island and Chernobyl, give us some sense of what could happen" (Giddens, 1990, 134). Modern threats create their own new belief systems and ideologies, I hypothesize. A possible indicator for a threat for humanity could be a measure of risk perception of a high risk technology, such as nuclear power.

The idea of perception and awareness, beyond rational reasoning and standardized procedures of risk assessment, can be the starting point of new forms of risk assessment and social learning. The question of the uncontrollability and the catastrophic potential of human created threats could guide human reasoning to a new empty space, creating new forms of communication to analyze and discuss social life in the future. Giddens' words guide towards a procedure of risk assessment that includes the enormous threat potential of modern risks: "The baseline for analysis hast to be the *inevitability* of living with dangers which are *remote* from the control not only of individuals, but also of large organisations, including states; and which are of *high intensity* and *life-threatening* for millions of human beings and potentially for the whole of humanity" (Giddens, 1990, 134).

The empty space, as mentioned above, is a questioning of the idea of expertise, as Giddens clearly points out, by criticizing expert's role in risk management. The fact that risk assessment does not cover the whole problem due to technical, social, and human factors, the dynamic of technological development does create a catastrophic potential with unintended consequences of technological progress: "More damaging than the lay discovery of this kind of concealment is the circumstance where the full extend of a particular set of dangers and the risks associated with them is not realised by the experts. For in this case what is in question is not only the limits of, or the gaps in, expert knowledge, but an inadequacy which compromises the very idea of expertise" (Giddens, 1990, 134). I would argue that expert systems within certain social risk environments are not free of losing the moral understanding of respectful awareness of knowledge. By respectful awareness of knowledge, I mean the awareness of the boundaries of knowledge and the open spaces of uncertainty that remain unnoticed.

According to Giddens, the limits of expertise and its uncertainties are closely related to the limits of institutions as such. Designed as closed systems, social institutions should be able to provide a space and a normative concept, such as laws and rules, for certain social activities. The institutionalized social space should be able to monitor, control, and sanction actors and their activities and, hence, control its own created risks. Modern institutions with their imperfect and disembedding mechanisms are not able to control risks entirely. Especially if the institutionalized mechanisms follow the idea to "outguess others in order to maximise economic returns" (Giddens, 1990, 128), such as in the case of technological competition, scientific knowledge markets, arms race, business, and in financial markets. Giddens also brings up that risks, designed as ""closed," institutionalized arenas of action" are also expected and desired as a source of power, like in the case of gambling or sports (Giddens, 1990, 128). Both arenas of action, where the chances of winning or loosing are calculable and the outcomes are uncertain.

In the case of outguessing the other in social arenas, not to lose is part of the institutionalized mechanisms. The institutions are not closed and linked to outside influences and, while outguessing the other, influencing outside social and natural systems: "Like in the arms race, the institutionalised risk environment of markets cannot be kept confined to its own "proper sphere." Not only do extraneous risks force themselves in, but the outcome of decisions within the institutionalised framework constantly affect those outside" (Giddens, 1990, 129). The arms race and the idea of protecting one's own institution from external and dangerous influences is an example of creating new risks by reacting to outside risks. I would argue that by giving one gun to the earth, there is no strategy involved of how to get rid of this massive threat for human life on earth. New institutions need to be created, a new awareness need to be evolve, new institutionalized laws implemented, and people need to be convinced to hand out their tools without using them. Yet at the same time the knowledge of how to produce and how to use those devices does exist as part of human knowledge for the rest of human history. The technology of war is an expert system, produced by human expertise.

3.1.4. Utopia – taking care of risks

The expert, the human entity as such, in an institution of organized human knowledge, is a risk for humanity: "Experts often take risks "on behalf" of lay clients while concealing, or fudging over, the true nature of those risks or even the fact that they are risk at all" (Giddens, 1990, 130-131). To this end, it is an individual's decision to create a risk or abstain from it. What if all humans are part of a risk system and we cannot minimize it? What are the next steps to create a system that incorporates the risk system, a über-risk system of humanity? What logic or what language is needed to form such a system in careful steps, still following the logic of modernity and the idea of outguessing the other, but within a different time-space dimension?

Giddens provides different answers (compare Rosa et al., 2014, 92–94). In his book he first describes a "post-scarcity order" (Giddens, 1990, 166), a "more coordinated global political order" of nation-states (Giddens, 1990, 168), to then pose the idea of an "overall system of planetary care" (Giddens, 1990, 170). He finally describes an "Utopian" state of the world, a reorganized modernity: "a radical reorganization of time and space" (Giddens, 1990, 178).

The concept of scarcity, Giddens explains, is based on the need structure of individuals and institutions, expressed in certain structures of thinking and acting out in life. It is a relative concept. Today's lifestyles are predominantly based on the concept of economic growth, an emergence of new ideas and markets to create and satisfy needs and expectations. A post-scarcity order would, according to Giddens, questions this lifestyle and market logic and also would question the logic of wealth: "While some resources are intrinsically scarce, most are not, in the sense that, except for the basic requirements of bodily existence, "scarcity" is relative to socially defined needs and to the demands of specific lifestyles. A post-scarcity order would involve significant alterations in modes of social life, and expectations of continuous economic growth would have to be modified. A global redistribution of wealth would be called for" (Giddens, 1990, 166). Giddens goes on to propose that a world order in peace is not unrealistic, although still yet utopian, from today's point of view, given the grown interdependences on a supranational level and shared or at least similar interests of national states (Giddens, 1990, 169).

The awareness of interdependencies may result in intensified coordination on a global political order and an awareness, rather the outguessing, of the global other: "So far as the relations between states are concerned it seems evident that a more coordinated global political order is likely to emerge. Trends towards increasing globalisation more or less force states to collaborate over issues which previously they might have sought to deal with separately" (Giddens, 1990, 168). These newly formed social institutions, beyond the pre-defined logic of political power and economic growth mechanisms, could follow a logic of care, including the ecological system, bringing in basic values of humanity into reasoning and decision making: "An overall system of planetary care might be created, which would have as its aim the preservation of the ecological well-being of the world as a whole" (Giddens, 1990, 170).

Giddens then proposes his potential order of the world, what he names "Utopia": "Utopian prescriptions or anticipations set a baseline for future states of affairs which blocks off modernity's endlessly open character. In a post-modern world, time and space would no longer be ordered in their interrelation by historicity. Whether this would imply a resurgence of religion in some form or another is difficult to say, but there would presumably be a renewed fixity to certain aspects of life that would recall some features of tradition. Such fixity would in turn provide a grounding for the sense of ontological security, reinforced by an awareness of a social universe subject to human control. This would not be a world that "collapses outward" into decentralised organisations but would no doubt interlace the local and global in complex fashion" (Giddens, 1990, 178). Giddens' Utopia has some restrictions and might be a break from the idea of openness. In my interpretation, openness might be a complete utopian state of modernity. The state of uncertainty, as the birthplace for entrepreneurial ideas as Knight (1921) outlined, or in the case of the open universe, described by Popper (1982).

In Giddens interpretation, the openness of his utopian worldview is disembedded from modern interpretations of time and space, religion, and social control. What prevails is an awareness of the global human other, an awareness of the local other and someone's belonging to a community. Humans in this sense are local and global entities at the same time, since the new time-space relations do not separate between both entities. As time becomes an individual interpretation, mobility between different places becomes far or close, fast or slow not in comparison to others but in line with someone's individual rhythm. Since the world then becomes one entity and a space of shared awareness society will transform and develop the abilities for dialogue (Giddens, 1994). The society is able to solve problems without armed conflicts. For Giddens, the mutual awareness of the other and each others time and space will from a global cosmopolitan society (Giddens, 2002).

3.2. Risk communities of humility

How to perceive risks and how to react to the known and unknown, the perceived and ignored risks today and in the future? How could humans organize themselves to create an awareness of risk? What could a social place look like? Risk might be something that is in us, part of ourselves and our community, not an outside threat. How could humans create an Utopia that makes Anthony Giddens feel satisfied or might be surprise to his line of thought? There is no single answer, yet. One approach, I argue, is to create decentralized risk communities that define their own time-space-dimensions depending on the risk they are responsible for. Such communities could combine communicative skills, trust, and social and technical experience to develop technical and social solutions. If trust is a crucial and central aspect for ontological security, as Giddens claims, creating trust in the communities by involving all relevant social actors is a mayor step towards any form of risk relationship and decision making. I would not start to define community as a given entity of size or place. Communities from my perspective define themselves through their perception of risk, that then defines their time-space-distance. The question of a waste disposal for nuclear waste creates different time-space-distances and forms a different community than the question of a waste disposal site or landfill for municipal solid waste.

Risk in this sense has its own character and social meaning because it has always been part of social and individual life. Risk perception then is an understanding of risk as a social entity. Risk also then is something to meet with respect, dignity, and awe. Maybe risk or the language that is used to find socially acceptable solutions for risks, will become more an religious, a self-reverencing, sounding character, or to recall Giddens' words: "the resurgence of religion in some form or another" (Giddens, 1990, 178).

3.2.1. Building resilient communities

The idea of describing risk as an element of social life, to be respected with awe, has been introduced by Sheila Jasannoff (2006). She calls her approach "Technologies of humility" (Jasanoff, 2006, 39), a concept that is based on four questions: (1) "What do we know about the risk and how do we know it?" (2) "Who is likely to be hurt?" (3) "How will losses be distributed?" (4) "How can we reflect most effectively on our collective experience of vulnerability and loss?" (Jasanoff, 2006, 41). The first question is the question of "framing" the problem, the second questions pleads for the "vulnerability" of society or a possibly affected community. The third question reflects the "distribution" of risk within the affected society, and the fourth question asks for the "deliberative" process that take place when risks are managed or governed.

Jasanoff's concept is a critique of traditional risk management and the predominant policy culture in most societies. Her reflections are around the theme of governing risks instead of managing them. Governing risks involves a broader aspect of societal knowledge than managing risks which emphasizes experts knowledge and clearly defined methods for making decisions. The adequate framing of a problem is important. A too narrowly or too broadly framed problem, or as she says a problem "simply [framed] in the wrong terms" (Jasanoff, 2006, 41) will result in solutions with the same deficiencies. According to her experience as a researcher, the reflection around the frame, the frame analysis, is an important feature, one that is most often an ignored aspect in policy-making. What is missing in the policy culture, from her point of view, are systematic methods to detect dominant approaches to frame risks. In line with her explanations, I argue that communicative techniques should be used to assess a risk's adequate dimensions, in Jasanoff's terms dimensions of narrowness or broadness, in Giddens' term the time-space distance.

The second focal point in Jasanoff's concept of the technologies of humility is vulnerability. Vulnerability changes the point of view from an outside perspective to a self-perceived inside perspective. Vulnerability changes the reference point and gives voice to the perceptions that exist within the community or defined social risk spaces. Jasanoff explains: "Risk analysis have traditionally viewed at-risk individuals or populations as passive objects in the path of the risk to be characterized. People are seen as exposed to the risks that the manager wishes to control; their exposure is then assessed through techniques of formal quantification. One problem with this approach is that the risk manager's judgement is taken as the reference point for determining vulnerability, rather than the affected subjects' self-perception" (Jasanoff, 2006, 41). What outside risk management or expert practices have in common is an oversimplification and standardization of affected individuals, creating aggregated entities when using statistical classification methods. The analyzes are based on objective physical or biological criteria, such as 'most exposed people,' or 'children or women,' ignoring differences within the groups or additional vulnerability factors, such as historical development of the communities or inter-social connectedness. From Jasanoff's point of view, the strength of communal knowledge and local networks does matter to a great deal, particularly for the resilience of communities in case of risk events. Jasanoff's approach gives individuals a participatory role, an active membership in the risk governance process, with the possibility of influencing decisions by contributing knowledge and local expertise. Her aim is to avoid expert discourses, distant and separate from regions and individuals at risks; and above all, to avoid that sophisticated, yet limited, techniques of risk management perceive the actual affected people as mere objects of analysis rather than vital and important sources of information and knowledge (Jasanoff, 2006, 42).

Her third focal point 'distribution' points to the inequality of distribution of losses. As examples of risks events where poor people were disproportionally affected by this events, Jasanoff mentions the tsunami in Asia in 2004 and hurricane Katrina in the U.S. in 2003. Her critique of a technical risk assessment: that exposure assessments do not adequately assess inequality. From her point of view, risk assessment procedures do not take into account people who are already poor because they seemingly have less to loose. In her concept of risk governance, poor people who are most vulnerable to risks, would also be taken into consideration. Jasannoff's aim is to design concepts for people at risk independent of their social status and social influence.

Deliberative practice of risk governance, in terms of deliberative thinking, deliberative learning, or deliberative settings, is the fourth part in Jasanoff's concept of technologies of humility. Her aim is to define a concept that is able to learn from its own practice. A deliberative practice is able to change and question risk management's basic assumptions. The concept enables to change the frame, the expert's practices and the predominant communication processes. A concept that is constantly questioning the core foundations of risk management, by focusing not only on causes but also on the context, by taking into account individual experiences and opinions as well as outside assumptions and objective measurements. A concept that also challenges today's risk institutions and their practices. Her critique is that people within their institutions resist to learn: "The capacity to learn is constrained, as I have suggested, by the limiting features of the frame within which institutions reflect on their prior actions. Institutions see only what their governing discourses and practices allow them to see. Thus the framework of risk assessment continually reorients the expert learner's attention back towards prediction, with its emphasis on improved modeling and management of cause" (Jasanoff, 2006, 43).

Jasanoff's focus is not on predicting risks, but on mutual learning, on collecting experience, on understanding different angles of observation. In her opinion, risks most often have a variety of causes and consequences which are open to interpretations and vary between different point of views. Deliberative learning is designed as a process to open institutionalized practices of risk management to a variety of opinions and perspectives for past and for potential risks. Risk governance, as Jasanoff claims and will also be discussed in more detail in Section 9, is designed as a social process that considers risks as ambiguous, uncertain, and complex (compare also Rosa et al., 2014, Chapter 8: 131-137). The process of risk governance beyond expert's knowledge activates society's potential in governing outcomes than can affect their social life in different degrees: "In the shift towards risk governance, the aim should be to construct institutions of civic deliberation, through which societies can reflect on ambiguity and assess the strengths and weaknesses of alternative explanations. Deliberative learning, in this sense, may be messier in its processes and more modest in its expectations than expert practices of calculating risk; but it would be rightfully more ambitious in seeking to learn from the full extent of relevant experience and in building, on that basis, more resilient societies" (Jasanoff, 2006, 43).

Risks in Jasanoff's perception are abstract and today all societies are risk societies

(Jasanoff, 2006, 38). Risks become real when they materialized into harmful events. Risk events harm and are “injurious events”, doing painful harm to the living body of society and actually “damage human lives and solidarity” (Jasanoff, 2006, 38). Jasanoff’s sense of words, in my opinion, reflects that human lives and grown social entities of any size and historical background are unique living entities, that are vulnerable and can be damaged and hurt. Society, from this perspective, can be interpreted as a living body or as a vital organism. Society, in that sense, is not a passive and distant object anymore. Important is the perception of the consequences: negative outcomes are events that hurt and injure societies and their individual’s lives.

Some events like a hurricane or an earthquake cannot be prevented, nor their consequences and damages for society. As a consequence, Jasanoff’s concept is designed to strengthen society, to make them more resilient when reacting to these events. From her point of view, risk management most often fails to predict risks and neglects the needs in the case of a harmful event: “Given the range and severity of injurious events that can overtake us unawares, and the woeful shortcomings of emergency response despite decades of expert risk management, perhaps the important question is not how to predict events more accurately but how to ensure greater resilience if and when they occur” (Jasanoff, 2006, 38). Her concept tries to convince that a deeper understanding of the social context, like the historical grown structures and the municipal organization of a community, will rather lead to less damage in the case of a bad event than experts’ predictive models of causes and probabilities, ignoring social inequalities and its fatal consequences for communities: “The challenge, in other words, is to move away from a near-exclusive focus on cause and probabilities – on calculating the incalculable – towards a deeper understanding of the contexts within which injuries are experienced, and often exacerbated with painful inequity” (Jasanoff, 2006, 39).

3.2.2. Beyond expert systems

Managing risks, as Jasanoff states above, is the practice of “calculating the incalculable” (2006, 39) whether the risks are predictable or not. Jasanoff’s idea of risk governance rejects superior perspectives and centralized system of knowledge and expertise and follows an approach that aggregates knowledge and experience starting from the bottom of society. Knowledge that in her point of view would not be accessible to scientific reasoning: “Governance, by contrast, draws its strength from below, by aggregating communal knowledge and experience, preferences and concerns, which no science has brought under its control. Humility, nut hubris, is the animating spirit of governance” (Jasanoff, 2006, 40). Governance opens the analytic horizon to a wider understanding of risk to go beyond methods of predictive sciences and a narrow framing of management procedures (Jasanoff, 2006, 29).

Historical events in the 20th century changed the nature and the meaning of risks yet the social processes to analyze and to understand risks are still based on methods that perceive risks as calculable and insurable: “The latter half of the twentieth century, however, gave rise to risks that escape humanity’s powers of prediction, in part because there is little or no direct historical memory to fall back on in evaluating them. Some are so infrequent, distant in time or causally complex that they are literally, as well as figuratively, incalculable; others arise through historically contingent human behaviours that no one, it seems, could have imagined, let alone foretold. Yet such risks may be catastrophic, at the level of individual as well as communal life” (Jasanoff, 2006, 29). She continues by mentioning nuclear technology and the possibility of a nuclear war to demonstrate that these incalculable and unforeseen risks are not only threatening entire human life but also not controllable anymore: “[N]ot only the continued threat of a nuclear holocaust but a succession of more or less devastating natural and human-made disasters have kept alive the spectre of essentially incalculable, and hence uninsurable, risks. How to govern *these* – not simply manage them – has emerged as on of the greatest technical and political challenges of the early twenty-first century” (Jasanoff, 2006, 30).

Governing today’s complex and trans-national risks has become a major task or challenge for today’s societies, independent of their national borders (Jasanoff, 2006, 31). Conflicts among affected people, experts, policy makers, and citizens might challenge the process of governing risks, especially by gaging policy relevant knowledge and by considering whose knowledge is reliable and explaining why: “How should conflicts among experts, interest groups and, indeed, national governments be resolved?” (Jasanoff, 2006, 32) Jasanoff keeps asking. Similar to Charles Perrow (1999) previously mentioned in Section 2.4.6, Jasanoff sees today’s risk discourse dominated by power-structures that undermine any attempts to open the risk dialogue to the public and, hence, to a real democratization of the dialogue: “... explore the troubling implications for democracy, as risk discourse and practice come to be dominated by powerful cadres of experts, allied with public and corporate policymakers, in the new, opaque formations of the regulatory state” (Jasanoff, 2006, 32).

Jasanoff criticizes the narrow scientific concept of risk assessment, especially the predominant assumption that the best experts will produce the best knowledge, and are able to classify risks according to their own defined measures: “From the technocratic standpoint, the dominant problems are to find the right experts and produce the best knowledge. Most risk worth worrying about, the technocratic perspective holds, can be estimated on the basis of solid data, good models and (in an increasingly popular phrase) ‘sound science”’ (Jasanoff, 2006, 33). From the technocratic point of view, lay people’s perception, if not in line with expert’s views, must be wrong because the best knowledge has already be considered and taken into considerations. From an experts’ perspective, public risk perception is full of methodological flaws and individual ways of reasoning. Laypeople most often judge affectively and emotionally, and, hence, are not comparable with rational reasoning. Sheila Jasanoff is asking about the skeptical views ordinary people hold on experts’ opinions: “Why do publics often respond negatively to risks that experts deem negligible? In looking for answers, expertise in risk analysis became coupled with tacit theories of public opinion formation. If publics worry unduly about small risks, many concluded, it must be because of technical illiteracy and poor understanding of science, superstition, media hype or manipulation by political interests. The study of public risk perception itself emerged as a new social science" (Jasanoff, 2006, 33). Jasanoff also criticizes the theoretical explanations of public risk perception research. Non-expert knowledge is assumed to be biased and distorted. "Such research [on public's risk perception] presumes that risk policy should not concern itself with distorting contextual variables that alter 'perception', but should look only at mathematically calculated probabilities of harm. It thus leaves intact the technocratic promise of being able to estimate risks with reasonable certainty and attributes the discrepancies between expert judgements and public perceptions to laypeople's inherent (and, by definition, distorting) cognitive biases. Rationality, for the expert assessors of risk, lies squarely on the side of scientific prediction and management. Concern about risks, especially those deemed small or negligible by experts, is correspondingly, and asymmetrically, labelled as biased or irrational, and treated as needing special cognitive explanation" (Jasanoff, 2006, 33).

Humans who are irrational don't need to be given the right to express themselves and hence don't need to be part of a political process, aimed at solving problems. This could be one interpretation of Jasanoff's critique on an experts' perspective, which assumes that public risk perception is irrational or distorted. If Jasanoff's interpretation of public risk perception research is true, the assumption of irrationality and distortion, as I will call it for now, is a very strong assumption able to excludes important information from risk decision processes with potentially fatal consequences for humans and their communities.

I conclude from Jasanoff's explanation that if scientific evidence shows that the assumption of irrationality and distortion can be rejected or at least cannot hold empirical prove, theoretical explanation of public opinions and public's expression of concern might be advised to question its basic assumptions on rationality. Public risk managers might consider incorporating all available knowledge so as to not to lose additional opinions and public evidence of potential risks and perceived risks. Governance might be a term that expresses the will of the elected or gained decision maker, experts, and representatives of the given power-structure, to listen to concerned public voices and to open up the dialogue to all available knowledge.

I conclude that the practice of mutual dialogues might be a keystone to form and foster an active citizenship, especially with regard to possible reactions, answers or solutions to known or ignored harmful risk situations today and in the future. An annoying but active public voice might be today's best teacher for discovering answers and measures that will help to build a global society of humility. First and foremost, most important for the purpose of scientific progress, the annoying public voice is the best change to question one's own assumptions and the foundations of my own scientific knowledge. Karl Popper's (1959) basic claim to finding ways to test its own basic assumptions is still one of the most demanding and challenging prerequisites for anybody who is in charge of knowledge and is in power to institutionalize knowledge. Jasanoff's attempt encourages us to constantly find a different angle for observing and describing social practices. She questions the socially accepted foundations of knowledge and opens up the dialogue to new practices. Her voice claims that knowledge is a value, needing to be kept and publicly expressed to improve human welfare (Jasanoff, 2006, 34).

Before analyzing public risk perception in more detail, I want to give Sheila Jasanoff the last word in order to shed more light on my research topic of individual risk perception and how I hope to contribute to the question: "Is it possible [...] to imagine a regime of democratic risk governance that allows for the possibility of change and yet makes room for the questions, doubts, fears and preferences of non-expert publics?" (Jasanoff, 2006, 35). I will focus on that question at the end of my empirical research when discussing how different socially expressed preferences can be incorporated in a concept of governance (Section 9). This is a necessary question to answer in the future, as Jasanoff suggests describing her idea of risk governance: "Such governance would foster discovery and innovation in a world in which, all concerned, zero risk is an unattainable ideal, but it would also take into account public preferences and concerns, as well as cross-cultural differences in wants and needs" (Jasanoff, 2006, 34).

Part II. Towards a deeper understanding of nuclear risk perception

4. Risk perception in social sciences

4.1. Risk perception as a multidimensional concept

An aware society evaluates risks from different perspectives, most often considering past experiences. In this sense, risk varies between individuals and has a historical beginning. Jasanoff argues: "whereas risk is normally seen as a property of the indeterminate future, a dark foreshadowing of things to come, I will argue that risk is better seen a projection of what we already know, have experienced and think we should control" (Jasanoff, 2006, 28). Regarding risk perception as an example of individual experiences with risk, different ways of interpreting and judging risks, seem to be an essential element of public's risk perception. Risk perception depends on individual's awareness and is empirically based on intuition, emotions, and past knowledge: "In this respect, risk is a product of human imagination, disciplined and conditioned by an awareness of the past. That awareness, moreover, is necessarily partial and selective: the past is not the same for everyone who experiences it" (Jasanoff, 2006, 28).

For me it seems that the social space of risk with its different sounds, shades, and densities of perception, is a space of risk perceptions, ranging from irrational intuitive feelings to rational technical accounting. Risk is a composition of empirical evidence, theoretical hypothesizing, and testing that reveals its contours of risk and its social perception among different cultures in varying degrees. Ortwin Renn and Bernd Rohrmann (2000b, 214-215) conclude that based on previous and ongoing research on risk perception, there is no clear tendency towards one of the above described extreme explanation approaches: "[...] neither the claim of irrationality as the main source of intuitive risk perception, nor the claim of a deterministic relationship between universal risk characteristics and perceived risk can be sustained in the light of empirical evidence presented." The shades of risk, observed through the authors' lenses spanning at least two decades of empirical risk perception research, are manifold, containing a universe of knowledge, not only regarding how people perceive harm or hazards, but most importantly how people perceive the state of their world. Risk judgements, in this sense as a socially shaped impression of the world, is a normative judgement of the ongoing processes of social and technical development: "In fact, risk judgements indicate more than just perception of riskiness – they reveal global views on the development of humankind, on technological progress, on the meaning of nature, and on the 'fair' distribution of chances, benefits and risks" (Rohrmann and Renn, 2000, 42).

Risk perception research, the mere dry and flat term, might reveal its hidden and vitalizing sound by perceiving the work of scientists as an attempt to mirror the beauty of human minds. Human minds might be worrying and looking fearfully into the mirror, they might be trusting and relaxed, or they might be enthusiastic and aware of themselves, all the while expecting or looking forward to the next sudden adventure. Risk perception research in that sense is more than the assessment of a term. For me it is the art of portraying vibrations in society and the attempt – only the attempt not the expectation – to create a composition of observable differences across and within societies.

Risk's multi-dimensional nature is a common characteristic, observable in empirical risk perception studies. The manifoldness of risk perception lays in the complexity and the multitude of possible individual and social factors that frame individual perceptions of risks. The empirical results question the predominant technical interpretation of risk as a product of probability and consequences (Rohrmann and Renn, 2000, 41). The richness and wealth of observable differences add knowledge and alternative explanatory patterns to the meaning and understanding of risk. Risk as a holistic concept is more than the prediction of future's negative consequences, as practiced in technical risk assessments. Risk perception is connecting to historical social consciousness, as Sheila Jasanoff mentioned above (Jasanoff, 2006, 28). Research on risk perception shows that the subjective awareness of risk is able to take into consideration subjective evaluations of future consequences, a variety of context factors, complex social views of the world, and intuitive mechanisms to deal with uncertainty and probabilistic information. Because risk is a multi-facetted concept, from a social science perspective, risk is perceived as a social phenomenon to be understood rather than as a technical thing to be controlled: "Furthermore, the experience of risk is not limited to the threat of facing harm in the future. It includes subjective predictions of possible outcomes, the social and cultural context in which the risk is experienced, the mental images the risk situation evokes, the perception of the players who are involved in the risk situation and the judgements about fairness and equity related to the distribution of potential hazardous events. In this sense, risk is a social construct rather than a physical entity" (Rohrmann and Renn, 2000, 41).

Assuming that future's risk management processes do need to involve public opinions to manage and react sufficiently, sustainably, and efficiently to actual or potential risks on a global scale, effective risk communication is essential. How people perceive risks can improve risk communication. Risk communication, as described by Renn and Rohrmann, is based on the exchange of information between all parties involved in a risk issue (Rohrmann and Renn, 2000, 42). A better understanding for all involved parties of how humans think and judge the magnitude of a risk and to what degree people accept risks is useful for an egalitarian risk communication process. More information than just tables of mortality rates and amount of accidents combined with numbers between zero and one – the range of probabilities – might help to assess risks adequately and equitably.

At least an understanding of alternative views helps to solve past conflicts and provides all involved actors to understand other people's opinions: "Whether the particular aim of risk communication is (A) advancing knowledge, (B) behavior modification or (C) co-operative conflict resolution, the awareness and consideration of people's existing risk perception is a precondition for successful work" (Rohrmann and Renn, 2000, 42). Renn and Rohrmann furthermore claim, that if the aim of risk management is to solve conflicts a deep knowledge about the alternative ways of human thinking, reasoning, and behavior, in short the awareness of a risk's multi-facetted nature, is essential to create an awareness of the consequences of individualized or institutionalized decisions (Rohrmann and Renn, 2000, 42).

In social sciences the term risk perception is the conventional definition of people's view on risks. "The term "risk perception" refers to people's judgements and evaluations of hazards they (or their facilities, or the environment) are or might be exposed to. Both experience and beliefs are to be considered" (Rohrmann and Renn, 2000, 14-15). It is assumed that people receive information about an actual outcome, like experiencing an accident, and process the information. People use mental processes to form opinions and attitudes with regard to the origin of the risk and the consequences. The information can be both related to experienced risks or to possible future outcomes of human action or natural events (Rohrmann and Renn, 2000, 14).

Important topics in social science research on risk perception are large-scale technologies, especially technology-induced hazards, like nuclear power (Rohrmann and Renn, 2000, 16). This hazards have become more prominent in public awareness after major nuclear accidents, such as Three Mile Islands (USA, 1979), Chernobyl (Ukraine, 1989), ad nd Fukushima (Japan, 2011). Other large-scale technologies are chemical industries, and the consequences of related accidents, such as Bophal (India, 1984), as well as more recent topics of genetic engineering or nuclear waste disposals. Risk perception research also became a relevant element in risk analysis when the discrepancy between expert's and laypeople's judgements and evaluations of risks became obvious and could no longer be ignored within the domains of risk research. As mentioned above, research on risk perception helps to complement the technical risk assessment process by creating an awareness of how people perceive and construct the reality with regard to undesirable consequences. In the next part I want to describe the very principles of risk perception research.[17]

According to Renn and Rohrmann (2000, 17–18) in social science, two approaches have been developed to study risk perception. The first approach, called the psychometric approach is primarily interested in laypeople's opinions about risks in contrast to experts' views. From this point of view, risk is a subjective concept and social criteria, not an objective measure. When including psychological aspects, scientists examine the

[17] In this part I will refer mostly on the study of Renn and Rohrmann (Rohrmann and Renn, 2000) and will add necessary information from primary literature to supplement the already very precise and excellent overview on risk perception research provided by the authors.

cognitive structure of risk perception by using different quantitative methods like factor analysis, structural equation models, or multiple regression. The cultural approach, as second approach, looks at risk perception from a macro-sociological perspective. In a rather theoretical than empirical way, social scientists define risks as socially and culturally constructed elements, determined by predominant norms, values and other cultural factors (e.g., Beck, 1992; Luhmann, 1990; Douglas and Wildavsky, 1983; Dake, 1992). From such a point of view, the context in which dangerous events occur or the risk of future hazards is discussed and assessed, determines individual's risk perception.

In my research, I am analyzing individuals risk perception on nuclear technology in a cross-national comparison using national survey data from the International Social Survey Programme (ISSP, 2012). I want to briefly outline the main approaches of quantitative empirical research on risk perception.[18]

Empirical studies on risk perception focus on different sources of risks or hazards[19]. Studies widely differ in their research question: some focus on a particular set of hazards, like activities, substances, or technological risks, while other studies focus on one specific risks, such as smoking or diseases like AIDS or Bovine spongiform encephalopathy (BSE). Nuclear energy is a major topic in empirical risk perception research, as Renn and Rohrmann point out: "most frequent issues are large-scale technologies, above all nuclear energy" (Rohrmann and Renn, 2000, 19). The studies on a specific risk subject can be further divided into studies of people who are actually exposed to a risk, such as people who live near a nuclear power plant or people working for a chemical factory, and studies of individuals who are asked to evaluate a risks without having been exposed to a specific risk.

In empirical studies respondents are asked to judge different risks aspects. In most cases the dependent variable, the variable of interest, is respondent's judgement or acceptance of the perceived magnitude of the risk. Beside risk's magnitude often additional qualitative features of a risk, such as dreadfulness, familiarity or controllability are asked. Other studies are interested in benefit aspects of the risk source or a judgement of the equitability of a hazard's or activity's risks and benefits. Additional options are to ask for the personal relation to hazards or the level of acceptability like the willingness-to-pay to reduce risks (Rohrmann and Renn, 2000, 20).

The empirical basis of risk perception research varies widely, according to Renn and Rohrmann (2000, 20, 22 (Table 4)). Most often convenience samples, like student groups or other ad-hoc samples are used to conduct risk perception. In some case, specific societal sub-groups like feminist groups, ecological oriented organizations, engineers or

[18] I do not wish to consider qualitative approaches such as interviews or focus groups, or content analysis (compare Rohrmann and Renn, 2000, 18) as negligible, but my scope and efforts are limited at that stage of my research and a more comprehend approach to understand the different dimensions of risk perception research might be subject of more detailed future research.

[19] ""Hazard" refers to a situation, event or substance that can become harmful for people, nature or human-made facilities" (Rohrmann and Renn, 2000, 14).

teachers are asked for their opinions. An disadvantage is the small sample size of empirical studies[20]. For these reasons, unlike the ISSP data set I am using in my research, most studies cannot claim to be a representative sample. In case of cross-national or intra-national comparisons the ad-hoc sampling is a problem because the comparability of results between countries is problematic and the validity of generalized results from the sample to a higher societal entity, like the whole country is questionable: "the restricted comparability and cross-validation can be considered as a disadvantage. In any case it is indispensable to check carefully a study's methodological approach before findings are interpreted and generalized"(Rohrmann and Renn, 2000, 23).

Scientists, who are interested in cross-national comparisons, most often do a comparison of two countries, most often the country they are based in, like in the case of Paul Slovic (2000a; 1987), a pioneer in risk perception research, the United States and other mostly European or developed western countries, such as France (Slovic et al., 2000a) or Japan (Hinman et al., 1993). Cross-national studies quite often focus on nuclear power and not on multiple or a set of hazards. Studies on Asian, African or South American countries are rare (Rohrmann and Renn, 2000, 20). Researchers are far from being able to draw a global picture of individual's risk perception.

In most quantitative empirical studies, the cognitive structure of risk perception is analyzed with statistical methods such as factor analysis, multiple regression, or structural or causal modeling. The comparison of risk judgements between different croups is most often analyzed using mean-difference comparison (ANOVA).

My empirical research (see Section 6, Section 7, and Section 8) focuses on the hazard of nuclear power and is related to the most frequently questioned risk feature: the perceived magnitude of nuclear risk. The data of the International Social Survey Programme (ISSP) allows for a cross-national comparison using representative national survey samples, an advantage of my studies. The scope of questions to evaluate individual's risk perception, is limited to the predefined set of variables and categories developed and tested by the ISSP's member committee.

4.2. Theoretical approaches of risk perception

If we consider risk as a socially constructed entity, based on information and social communication (compare, Luhmann, 1986; Rohrmann and Renn, 2000) about an actual or possible hazard, the way people perceive or judge information and how they actually construct an opinion, is a central question for explaining the emergence of risk perception.

[20] Compare research by Fischhoff et al. (1978) as an example for a small and selective sample.

4.2.1. Heuristics: intuitive reasoning of probabilistic information

Heuristics are intuitive mechanisms people use to process information to judge a situation or alternative situations. Intuitive heuristics are especially important to process complex or uncertain probabilistic information (Rohrmann and Renn, 2000, 24). In every day life, people usually try to reduce complexity by drawing inference of a limited degree of information. The way people process probabilistic information and judge risks is not based on the expected value approach, predominantly used in scientific risk assessments. Psychological studies show for example that participants most often choose risk averse decision options when possible losses are high and choose risk prone decision options when the possibility of gaining something seems high (compare e.g. Kahneman and Tversky, 1979). The intension to balance risk taking behavior can be observed when people choose to avoid major losses rather than to maximize their gains (Rohrmann and Renn, 2000, 25). Studies that try to explain human's perception of probabilistic decision making come to the conclusion that if the expected value is taken as reference point, people show deviant behavior in drawing inferences from probabilistic information. These, from the probabilistic's point of view, observed anomalies, are called biases[21]. Biases are the dominant term to describe discrepancies in human behavior violating logical rules (Rohrmann and Renn, 2000, 25).[22]

The following biases are discussed in literature most often:

1. **Availability bias**: events or situations, that are immediately available to people's awareness are perceived as more probable than events that are not immediately mentally accessible (Rohrmann and Renn, 2000, 25; see also Tversky and Kahneman, 1973; Lichtenstein et al., 1978, and Boholm, 1998, 138).

2. **Anchoring effect bias**: probability judgements are biased towards the immediate first available information or the "perceived significance of the information" that comes into one's mind (Rohrmann and Renn, 2000, 25; compare also Rottenstreich and Tversky, 1997).

3. **Representativeness bias**: particular events experienced or events that can be related to familiar properties or known situations are perceived as more typical or likely than events based on dry information represented by relational numbers such as frequencies or probabilities (Rohrmann and Renn, 2000, 25).

[21] Why they are called biases or even irrational reasoning is a discussion I do not want to go into here. I think I am in line with Jasanoff as shown above (Jasanoff, 2006, 33). I think that scientific theories, and their underlying assumptions, their historical development, and the different discussions within a scientific-discipline, need to be reflected from a meta-theoretical perspective, before theories are employed to explain irrational or biased behavior. Probabilistic reasoning is a specific way of perceiving the world. Probabilistic thinking based on expected values is a highly artificial way, given the underlying assumptions, that the reality is expected to be known (Gigerenzer, 2008a, 2003, 1996, 1991; Ellsberg, 2001, 1961).

[22] Compare Tversky and Kahnemann (1974) for an overview of the concept of heuristics and biases and for a critique see Gigerenzer (1991).

4. **Avoidance of cognitive dissonance bias**: situations or events that directly influence an individual and after processing the information are challenging someone's existing belief system, are tend to be ignored to different degrees (Rohrmann and Renn, 2000, 25; compare also Rohrmann, 1994).

The interesting question to me is how people use information to judge risks. There is an observed gap in laypeople's perception and expert's judgements of risk situations. Heuristics may be one explanation for the observed discrepancies, even though the external validity of the above mentioned laboratory studies is limited. Every day situations provide more information and are more familiar to people than artificial scientific experiments designed to create judgements based on numerical information such as relative frequencies (Rohrmann and Renn, 2000, 25).

4.2.2. Psychometric – qualitative – aspects of risk perception

What are the qualitative characteristics of risks that shape individual risk judgements and estimations? This is the main question in this section. How laypeople attribute certain characteristics of risk sources, as well as attributes to a hazard's outcome, is of interest. The assumption is that each type of risk has its own situational characteristics which vary between individual's opinions (Rohrmann and Renn, 2000, 26). What is of interest, to borrow Paul Slovic's book title, is the 'Feeling of Risk' (Slovic, 2010). The feeling of risk is influenced by external attributes like the expected number of fatalities or losses and the catastrophic potential of a risk. Whereas the actual number of fatalities correlates only weakly with risk perception, as empirical studies indicate (Rohrmann and Renn, 2000, 26), the catastrophic potential of low-probability high-consequence risks seems to cause strong feelings of dread. Dreadful events are more threatening to respondents than risks with the same or higher expected value but lower catastrophic potential, even if the probability of the risks are to be regarded as more likely. The most prominent example is the example of nuclear accidents and car accidents. Car accidents are according to their expected value of fatalities and losses more dangerous than the rare events of nuclear accidents, but are perceived as less dangerous.

Beside this more general distinction based on the catastrophic potential of a risk source or its potential outcome, more specific attributes of risks are evaluated and observable if respondents are asked to distinguish between different properties associated with a risk (Rohrmann and Renn, 2000, 26). The most common qualitative aspects of a risk are a) a risk's perceived dread potential regarding the possible consequences, b) the familiarity of a risk source, and c) a person's perceived personal control over the consequences and the probability of occurrence of a risk. Further important qualitative risk characteristics are institutional control and the potential to blame specific social institutions or individual persons who are responsible for the risk situation. Qualitative aspects measure how equal benefits and losses in case of a risk are distributed among the affected people.

Furthermore, the potential to take a risk voluntarily or being involuntarily exposed to a risk, is also an aspect in risk judgement.

There is also evidence that people associate their own beliefs or belief systems with the causes of risks. For example in the case of technological risks beliefs about technology are associated, in case of a natural disaster the beliefs about ecology and nature are associated. With regard to the assumption of cognitive dissonance, i.e. the avoidance of emotional stress and conflicting feeling due to new information that challenges one's existing belief-system, one can explain why respondents who associate positive attitudes to a risk source rank a risk as less threatening and more threatening when negative emotions are associated with the underlying beliefs of a risk source (Rohrmann and Renn, 2000, 27).

To examine the relation between the above described qualitative characteristics and individual risk evaluation, it is important to discuss each characteristic's assumed potential effect (Rohrmann and Renn, 2000, 26 (Table 6)). An increase in risk tolerance is assumed to be observed among respondents when risks are characterized as personally controllable, taken voluntarily, and perceived as familiar. Risk tolerance decreases when risks are perceived as a dread, if risk sources are artificial or human induced, and if a risk's benefits are distributed inequitably. If institutions are perceived to be responsible for a risk source or can be held accountable, the individual risk tolerance depends on the trust and confidence in the respective institution or the given political system.

Such qualitative aspects of risk perception and evaluation have been analyzed with factor analytic methods to aggregate the single characteristics into main factors. Scientists analyzing the factorial structure of risk aspects most often find a two factorial solution. The first factor is the dreadfulness of a risk and second the familiarity of a risk or the degree of knowledge of a hazard (Rohrmann and Renn, 2000, 29-31). According to Slovic (see for an overview: Slovic, 2000a, 224-225; see also Slovic, 1987) the first factor 'dread' contains risks that are characterized as uncontrollable, dreadful, catastrophic and/or of global catastrophic potential, with fatal consequences, not equitably distributed, are a high risk for future generations, not easily reduced, are risk increasing, hence, are not balancing gains and losses, and are involuntary. Among the evaluated risks, nuclear weapons and nuclear power score highest on first factor's characteristics (compare Figure 5 on page 73). The second factor, 'familiarity' of a risk or 'unknown' risks, includes risks that are judged as not observable, to having delayed effects, are new, and unknown to people and science. New technologies like chemical or biological technologies score high on this factor. A third factor comprising the number of people, exposed to the risk is observed in several studies.

In regard to laypeople's perception of risk the first factor 'dread' seems to be correlated to people's critical evaluation of risks. Slovic reports that risks scoring higher on the 'dread factor' are also risks, respondents wish to see stricter regulations from public authorities (Slovic, 2000a, 226). Slovic's research on individual risk perception reveals that experts' perceptions of risks differ widely from laypeople's opinions when judging

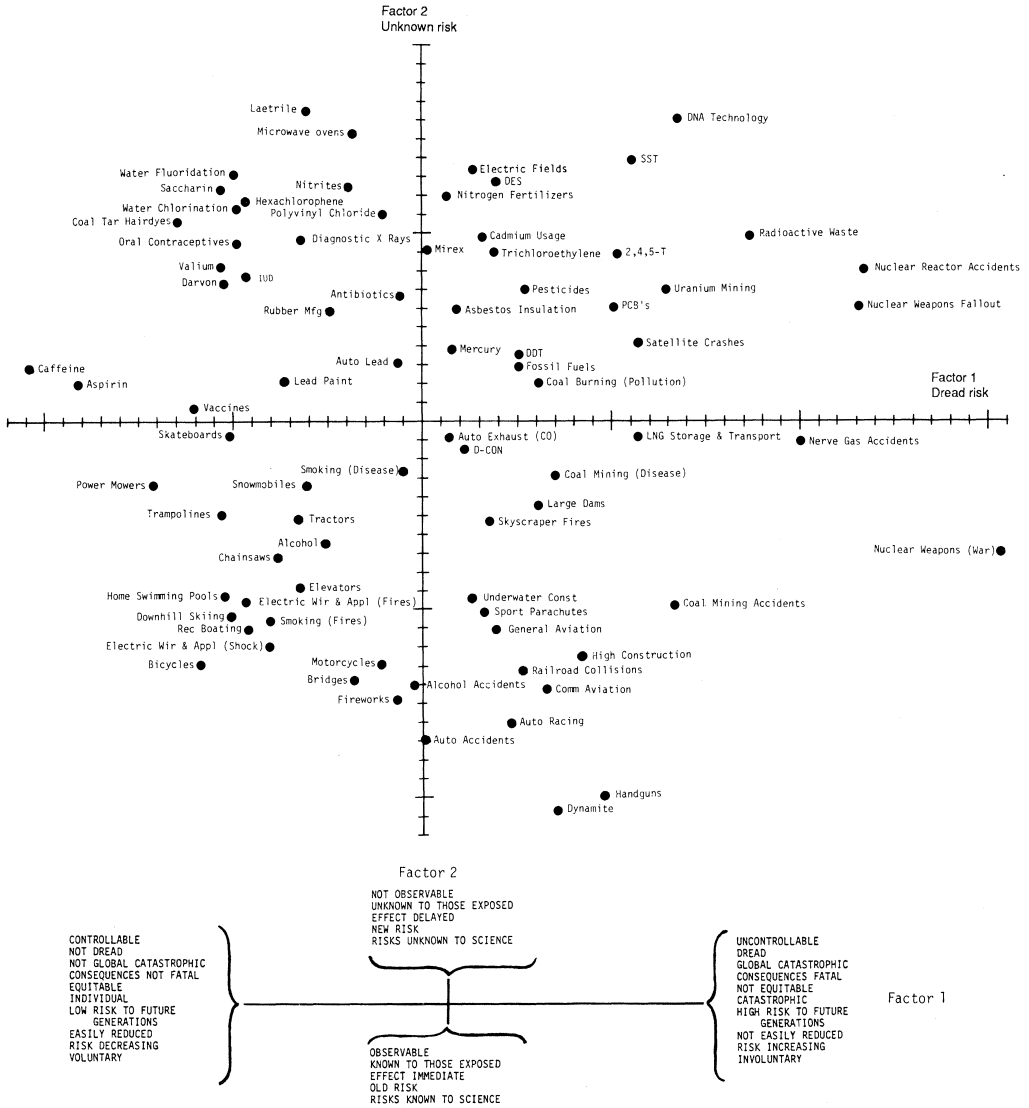

Fig. 1. Location of 81 hazards on factors 1 and 2 derived from the relationships among 18 risk characteristics. Each factor is made up of a combination of characteristics, as indicated by the lower diagram (*25*).

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(Source: Slovic, 1987, 282, Fig. 1.)

Figure 5: Two-dimensional factor space of risk perception.

risks and specific risk characteristics (Slovic, 2000a, 226, 224 (Table 13.1)). Summarizing studies on the psychometric paradigm he concludes laypeople's opinions depend on the context the problems or risks are set in. Laypeople's judgements can be based on the hard facts of annual fatalities, if asked for, but also depend on softer qualitative and situational aspects. Experts' views on risks, in contrast, are strongly based on, or gravitate towards, the common technocratic view of perceiving risks as annual fatalities (Slovic, 2000a, 223).

It seems to me, that laypeople take a more heterogeneous view of the world, allowing a-priori for a higher diversity of information. That knowledge is not necessarily based on more precise information, in terms of numbers and figures. If risk perception is related to feelings, the social context and the perception of one's social context intuitively influences risk opinions. The intuitive judgement of risks reflects how safe people perceive the world or their individual social context to be. Slovic argues that a gap between experts' and laypeople's opinions can indicate that people are not willing to accept the level of risks they perceive in their social environment. He claims that "the gap between perceived and desired risk levels suggests that people are not satisfied with the way that market and other regulatory mechanisms have balanced risks and benefits" (Slovic, 2000a, 223). Regarding the balance of risk, intuitive judgements about risks could serve as an indictor how well social mechanisms are functioning to guarantee an acceptable safety level and a feeling of comfort. I conclude that if the imbalance between perceived and current risks is high, an unwanted event like a nuclear accident, can have drastic consequences for a society. In emotionally laden risk environments there is a high social sensitivity or emotional activation potential to implement changes in order to change the existing safety structure.

I furthermore argue that either form of information, laypeople's feelings as well as experts' knowledge about a state of the world, are at any time only initial views. New evidence is able to change this initial view, but there is no guarantee that people are actually willing or even able to change their beliefs. In case of new evidence, an update of someone's initial (a-priori) information can vary drastically. On the one hand new information can lead to no change, on the other hand new information can drastically change someone's initial views. Research indicates that new information that does not challenge the existing belief system, is more likely to be interpreted as reliable than new evidence that contains disturbing information: "[...] disagreements about risk should not be expected to evaporate in the presence of evidence. Strong initial views are resistant to change because they influence the way that subsequent information is interpreted. New evidence appears reliable and informative if it is consistent with one's initial beliefs; contrary evidence tends to be dismissed as unreliable, erroneous or unrepresentative [...] When people lack strong prior opinions, the opposite situation exists – they are at the mercy of the problem formulation. Presenting the same information about risk in different ways (eg, mortality rates as opposed to survival rates) alters people's perspectives and actions" (Slovic, 2000a, 223).[23]

In their research Kahneman and Tversky (compare for example Tversky and Kahneman, 1981, 1982; Kahneman and Tversky, 1984; Kahneman, 2003) the authors express that the framing of a situation influences an observer's perspective and can result in different decision making processes. From their view, negatively described situations, for example a description of an outcome framed in number of fatalities instead of survivors, lead people to want to avoid these situations. Similar situations framed differently, for

[23] The author cites research of Nisbett and Ross (1980) regarding people's resistance of initial views and refers to Tversky and Kahneman (1982) regarding risks presented in different ways.

example by mentioning the number of survivors, helps the decision maker accept the situations (Tversky and Kahneman, 1981). The authors conclude, that the framing of a situation has an effect on how people evaluate the situation, even if the information and facts related to a risk, e.g. the number of fatalities and survivors or the likelihood of an event, remains the same. Kahnemann and Tversky furthermore conclude that invariance of information, as assumed in the rational choice paradigm, cannot proof to hold in real life decision making processes (Kahneman, 2003, 703). The evaluation of a situation seems to be more influenced on how easy people can approach and understand the situation they are judging. The framing of a situation is perceived as given and accepted. I suggest that the framing of a situation is correlated with the individual degree of ignorance, unconsciously reverberating the sound in the risk environment.

4.2.3. Ripple effects – the drop in the tea cup

The art of change, as I interpret it, is the art to constantly be willing to perceive one's views and ideas as incomplete, outdated, and willingly, although not necessarily consciously, ignoring information. It is a process of avoiding to be on either side of the extreme: of not being absorbed by the randomness of the constant endless stream of new human ideas and events happening in the present moment, all the while, not being resistant to change by ignoring emerging evidence of very slow or sudden developments. To me it seems that the stiff and set concept of experts' risk interpretation, a concept that is only appropriate in case of sound empirical evidence, has created the perceived imbalance between accepted and desired risks.

In the case of risks, the common procedure of only considering direct consequences to victims as relevant information to evaluate risks is not appropriate. Research on historical events reveals that in case of accidents, such as a nuclear accident, the impact of such an event spreads beyond the direct or expected costs of an extreme event. An unwanted event can cross social boundaries and affects companies and industries who are not or only to a minimal extend related to the accident. Paul Slovic calls this spread of impact, from the initial impact to outside and only distant related social places, "ripple effects" (Slovic et al., 1984; Kasperson et al., 1988; Slovic et al., 1991). Ripple effects are like the last drop of tea poured out of a pot of Japanese green tea that drops in the center of a full cup of tea: "[A]n unfortunate event can be thought of as analogous to a stone dropped in a pond. The ripples spread outward, encompassing first the directly affected victims, then the responsible company or agency and, in the extreme, reaching other companies, agencies and industries. Some events make only small ripples; others make larger ones" (Slovic, 2000a, 227). As an example Slovic describes the consequences of the Three Mile Island (TMI) accident in 1979, with no direct fatalities and only few known fatalities from related health damages. The company owning the utility had huge financial damages. The ripple effects crossed company's boundaries in that sense that stricter regulation and new safety standards were imposed on the industry by U.S. agencies, leading to higher costs for operators and consumers nationwide. The consequences rippled beyond national boundaries with consequences for the nuclear industry and the operation of nuclear reactors all over the globe. Furthermore, greater public opposition to nuclear power emerged as consequence of the accident with far reaching consequences for nuclear technology in the future. Slovic concludes that traditional analysis and a mere economic view on the costs of risks are ignoring the “higher order impacts of an unfortunate event” (Slovic, 2000a, 227).

One important factor to determine the seriousness of an event the perceived risk and public's risk judgement. The seriousness or the “signaling potential” (Slovic, 2000a, 228) of an event is related to the dread factor described above. A negative event in an unfamiliar system, like a nuclear power plant, might reveal the obviously catastrophic potential of the technology as well as hidden associations with that unknown and dreadful technology.[24] Indeed, people's negative emotions, fears and anxieties with nuclear technology, are not only associated with the danger of a nuclear accident but also with the existence, use, and development of nuclear weapons (Slovic, 2000a, 229-230). In that sense one might conclude that riding a train might be riskier in terms of fatalities, but the total number of train wrecks in the past might have no impact of observable ripples in your cup of tea; there is no last drop of tea left in your tea pot of past memories when it comes to a train wreck, the surface of your tea stays calm, unless you or somebody you know have been on the train. In contrast, you can still feel and see the ripples created by the nuclear bombs of Hiroshima and Nagasaki. This drops of tea are still present in your tea pot of human memories and constantly dripping in my cup of tea.

These long lasting memories might be one reason for the opposition against a specific technology like nuclear power, even though experts assume that this technology is safe. It seems that experts' tea pots of nuclear memory are empty. From laypeople's perception, the tea pots are full and emptying the pot is not possible because, as Slovic emphasizes, nuclear energy is not seen as beneficial to the whole society given the unacceptable high risks (Slovic, 2000a, 229). He explains the observable opposition among population by the extreme positions nuclear technology takes in the psychometric factor space, as described above. Nuclear technology is perceived as uncontrollable, unknown and unfamiliar, dreadful, inequitable, catastrophic, and assumed to affect future generations. At the same time people are aware that not so many people have died because of nuclear technology. And still, both perceptions, the quite low number of fatalities and the extreme dread potential of nuclear technology are not contradictory for laypeople, as Slovic's studies show.

Referring to the potentially high impact on ripple effect Slovic (2000a, 230) concludes

[24] The catastrophic potential in the case of an accident can be described in Ortwin Renn's semantic image of the “Damocles Sword”, a risk perceived as a random event that bears large catastrophic potential and comes like a disaster without any warnings and chance to prepare (Rohrmann and Renn, 2000, 27). In addition to the Damocles Sword Slovic brings up the image of an herald who is“a harbinger” of more dramatic mishaps in the future, caused by the same technology. The TMI accident can be interpreted as a herald of more dramatic accidents or consequences of nuclear technology (Slovic, 2000a, 228).

that for nuclear technology, even a small accident like Tree Mile Island might have large consequences across social boundaries. One reason is that the topic will get attention in the media. Slovic further points out that experts' attempt to educate people to prove that nuclear is safe enough for human societies will fail because of the lack of empirical evidence. Doubts about the technology will always remain because this technology cannot be proven to be managed and governed safely: "Attempts to 'educate' or reassure the public and bring their perceptions in line with those of industry experts appear unlikely to succeed because the low probability of serious reactor accidents makes empirical demonstrations of safety difficult to achieve. Because nuclear risks are perceived as unknown and potentially catastrophic, even small accidents will be highly publicized and may produce large ripple effects" (Slovic, 2000a, 230).

Nuclear technology is not a good pupil. It is a stubborn child, not accepting given rationalities. It has the catastrophic potential, similar to the image of a Damocles' Sword. In the case of nuclear waste, a problem not discussed in this dissertation, nuclear technology can also be perceived as a slow killer, a "Pandora's Box" as Ortwin Renn (2000, 28) pictures. A risk that is an invisible threat with delayed effects, non-catastrophic and transmitted by information rather than personal experience, a risk people need to express high levels of trust to institutions responsible for managing that risks. The claim to governing nuclear risks in a responsible way for future generations is a challenge for today's risk entrepreneurs.[25]

4.2.4. Rationality and chaos

It seems to me that there is a conflict in society between how different people, experts as well as laypeople, perceive and respond to uncertainty. Otherwise I cannot explain

[25] I use the term risk entrepreneur in the sense introduced in Section 2.4.4 by Knight (1921), to use a more vague or open term of a risk manager. The term risk experts as I have used it so far in my dissertation is meant to be an ideal type, used as the prototype of a mind that only counts a narrow idea of scientific reality, based on rational logic and ideal numbers. I am also picturing the risk expert as a prototype of scientific chauvinism as Paul Feyerabend had been noticing in the scientific community. Traditions of thoughts that either want to removed or re-educate incompatible voices, methods and its results: "Scientific chauvinism triumphs: 'What is compatible with science should live, what is not compatible with science, should die'. 'Science' in this context means not just a specific method, but all the results the method has so far produced. Things incompatible with the results must be eliminated" (Feyerabend, 1993, 36). A risk entrepreneur might be the prototype then of an incarnated risk governance creature, an master of risk governance, an artist, a care taker. I have to confess, my inner picture of my risk expert's prototype, I have never met one, is based on second hand information like the one mentioned above by Charles Perrow, Sheila Jasanoff, or in this case by Paul Slovic. Slovic cites an expert who expresses his anger about laypeople's irrational fears of nuclear power: "A nuclear physicist and leading advocate of nuclear power contented that: 'The public has been driven insane over fear of radiation [from nuclear power]. I use the word "insane" purposefully since one of its definitions is loss of contact to reality. The public's understanding of radiation dangers has virtually lost all contact with the actual dangers as understood by scientists' " (Slovic, 2000a, 229).

why there are voices claiming that laypeople should be better 'educated', as Slovic mentions (Slovic, 2000a, 230). Furthermore, experts interpret peoples judgements under uncertainty as 'irrational' or 'biased', as proponents of early heuristic research point out (compare Section 4.2.1). Michael Smithson (2008) describes the roots of this social conflict by outlining and exemplifying the results on psychological research on how people respond to uncertainty. It seems that the underlying assumptions of people who judge other people's judgements as irrational or biased are the assumption that humans cognitive capacities are limited (Smithson, 2008, 209; Jaeger et al., 2001, 152) and certain people do not use their full cognitive capacities. Hence there are judging people, perceived as smart, and judged people, who are deemed less smart regarding uncertainty. This basic underlying assumption, from my point of view, is that experts are by definition smarter and experts' views by definition more true. Do we observe a self-fulfilling prophecy, when people are judged as more or less smart?

Research results conclude, that people scoring higher in tests of mental ability and performance, behave more in line with probability theory and are not led systematically astray by heuristics (Smithson, 1997, 2008, 210).[26] The rationalist model has been criticized by the school of bounded rationality. Herbert Simon's bounded rationality approach (Simon, 1982) assumes that humans, or organisms, have limited capacity to process the complexity of information, but decision making is strongly influenced by the structure of the environment. This means that a social environment is influencing the decision making process: "The environment we shall discuss initially is perhaps a more appropriate one for a rat than for a human. For the term *environment* is ambiguous. We are not interested in describing some physically objective world in its totality, but only those aspects of the totality that have relevance as the "life space" of the organism considered. Hence, what we call the "environment" will depend upon the "needs," "drives," or "goals" of the organism, and upon its perceptual apparatus" (Simon, 1956, 130). For Simon there is not only humans and their characteristics, like intelligence, but also the constraints due to the characteristics of one's life space. Decisions in uncertainty are limited to all of these constraints. Smithson further explains bounded rationality as an approach that reflects the way humans make trade offs between cognitive efforts and the needed or wanted accuracy of a judgement. Humans, he concludes, adopt their cognitive capacities to the necessities that are set by the environment (Smithson, 2008, 210). Furthermore, many real-world situations do not reveal enough information to allow for an optimal decision strategy.

[26] Hogarth (1980) gives examples of situations in which people do not follow probabilistic theory and give biased responses like in the example of the gambler's fallacy (Kahneman and Tversky, 1972). The gambler's fallacy is a tendency to believe that a data generating process, that creates ideally randomly created events over an endless period of time, is itself self-correcting. That means, if an event, like an nuclear accident, is happening more frequently than expected, it will be expected to be less frequent in the future; or if an event, like an nuclear accident, is not happening in the expected way, it will happen more often in the future. Voices who prophecies after a nuclear accident that an accident will not happen soon again or see more accidents happening in the near future are trapped in the gambler's fallacy.

Smithson further refers to research that shows that heuristics are fast and frugal decision making processes and hence appropriate in realistic environments, even though they are perceived as suboptimal compared to normative strategies, based on probability theory: "[H]euristics used by people that are fallacies in the casino are effective in more realistic although uncertain environments" (Smithson, 2008, 211). In his own research (Smithson, 1997) he compares people's judgement of chaotic processes and of random processes. Chaotic processes like weather forecasts, turbulences or stock-market performances are difficult to predict, hence, uncertain in the long run, even though the underlying processes are deterministic (compare also Figure 4). The long term prediction of chaotic processes is difficult, because chaotic processes are sensitive to minor changes in the influencing factors, therefore they are not assumed to reach stationarity but are aperiodic and anti-persistent.

Smithson assumes that humans' decision making capacities are designed to judge chaotic processes and are able to adapt to chaotic environments because there is empirical evidence that numerous natural processes are chaotic in the sense of deterministic chaos. Smithson questions the basic assumption in standard normative theories of stochastic processes, defining stochastic processes as a sequence of independent events gravitating towards a stationary equilibrium in the long run: "It is worth mentioning that many natural processes exhibit (anti-) persistence and nonstationarity, whereas standard normative theories of judgement and decision making assess human performance against strategies which are optimal only for processes that are stochastic (i.e., with independent event) and stationary" (Smithson, 1997, 65). He observes that people judge chaotic processes better than random processes in terms of accuracy and under-dispersion. He points out that the observation of less under-dispersion is an important feature indicating that the extreme fluctuations of chaotic processes are taken into consideration by people's judgement and awareness of chaotic processes. In that sense, he concludes that people judge the extreme events or outcomes of chaotic processes better than of probabilistic processes (Smithson, 1997, 65).

I feel it is interesting to question the assumption of stochastic and probabilistic processes as criteria for rational decision making. The normative assumption of an equilibrium and stationary tendency of probabilistic processes is questionable as well as the assumption of risk environments as random spaces. If chaos and not randomness is the underlying process of many natural and social events, probabilistic reasoning might not account for extreme events properly. In that sense people's heuristics might be more sufficient for risk environments and deserve to be taken into consideration in risk assessment processes. I assume the case of a nuclear accident or a nuclear war to be a chaotic rather than a random event, based on a sequences of deterministic processes and not on stochastic processes, even though the underlying processes are not well known to human knowledge.

4.2.5. Risks as feelings

Feelings are considered to play an important role in judging risks and can be perceived as a factor explaining the discrepancy between experts' and laypeople's judgement on perceived risks. Loewenstein and colleagues (2001) question whether the empirically observed gap is caused on how risks are processed cognitively or affectively. In their risk-as-feelings hypothesis the authors conclude that firstly emotional responses for probabilities and outcomes, the two dominant factors for traditional risk assessment, differ from cognitive judgements of people named by the authors as "cognitive consequentialists" (Loewenstein et al., 2001, 274). Secondly, there are factors that influence emotions, but are not recognized as influential factors in cognitive evaluation. Emotional responses to risks are perceived to be more insensitive to probability changes. The insensitivity as such depends on the emotional impact related to the outcome. Small probabilities tend to be overweighted, for outcomes that are easy to imagine and that evoke negative emotions like fear or dread in the case of negative outcomes, as well as positive emotions like hope in the case of positive outcomes (Rottenstreich and Hsee, 2001).

Different emotional reactions that form subjective probabilities are able to explain differences in experts' and laypeople's risk evaluation of low-probability high-consequence risks like nuclear power. Loewenstein and colleagues include additional factors into their risk-as-feelings model that might influence people's emotional reactions to risks. The factors they name are vividness, how people can imagine a risk's consequence, experience and personal exposure to the outcome, as well as the past history of conditioning (Loewenstein et al., 2001, 271). These features are subjective feelings and emotional processes that differ from rather objective features used in cognitive assessments, like probabilities and impact of consequences.

For me, the question of whether emotions are problematic or useful for risk judgements is open. Psychological research alleges that emotions play an important role and blocking emotions might result in negative consequences to the decision making process: "In contrast to the historical view of emotions (and other "passions") as destructive influence on decision making, much of the new work highlights the role played by emotions as informational inputs into decision making and the negative consequences that result when such inputs are blocked" (Loewenstein et al., 2001, 268).

Antonio Damasio's "somatic marker hypothesis" (Damasio, 1994) presents a school of thoughts that highlights the importance of emotions. Damasio posits that somatic reactions are part of individual's judgement of different alternatives by providing relevant information about the desirability of each option. If these emotional reactions are blocked, the decision making process is impaired, even if all cognitive abilities are functioning properly. Research by Wilson and Schooler (1991) further indicate that people's ability to make decision is also impaired if people are asked to consider systematically all of the advantages and disadvantages of all available alternatives. The authors conclude that suppressing affective inputs by considering all information to carefully results in preference choices that are not optimal. Zajonic (1980) contributes evidence that affective reactions happen faster than cognitive evaluations. These immediate emotional reactions can be interpreted as driven by deep rooted or high-priority concerns that indicate the awareness of an impending danger (compare Loewenstein et al., 2001, 268).

Given the obvious impact and necessity of emotional reactions and evaluations on people's decision making processes, Loewenstein et al. develop the already above mentioned risk-as-feeling hypothesis. The risk-as-feeling hypothesis is combining emotional and cognitive evaluation processes based on outcome and subjective probability judgements and factors like vividness, immediacy, and experienced memories. The hypothesis "[...] postulates that responses to risky situations (including decision making) result in part from direct (i.e., not cortically mediated) emotional influences, including feelings such as worry, fear, dread, or anxiety. People are assumed to evaluate risky alternatives at a cognitive level, as in traditional models, based largely on the probability and desirability of associated consequences. Such cognitive evaluations have affective consequences, and feeling states also exert a reciprocal influence on cognitive evaluations" (Loewenstein et al., 2001, 270).

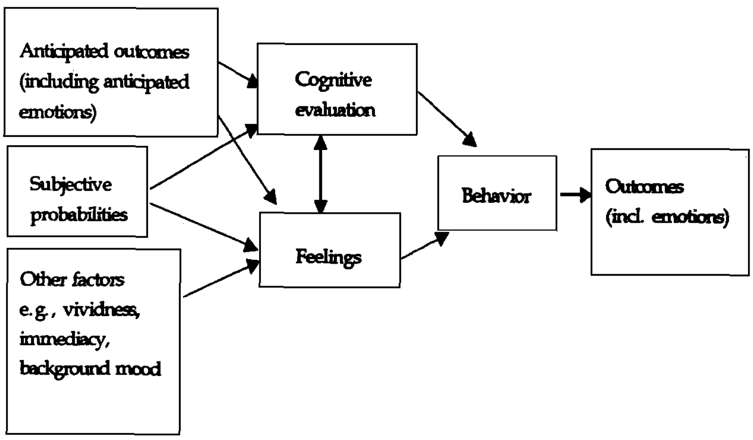


Figure 3. Risk-as-feelings perspective.

(Source: Loewenstein et al., 2001, 270, Fig. 3)

Figure 6: Risk as feelings: factors influencing individual's risk evaluation.

A graphical overview Figure 6 of the risk-as-feelings hypothesis as presented by Loewenstein and colleagues (Loewenstein et al., 2001, 270) summarizes the influencing factors and the assumed influence of feelings on behavior[27] or decision making and outcomes like a risk judgement.

[27] The authors emphasize how they purposefully use the term behavior instead of the commonly used term decision to indicate that emotionally driven risk evaluation processes can be observed in extreme panic reactions as well as agoraphobic fear and the inability to be in public spaces. Both are emotional reactions that do not fit well into the standard scheme of rational decision making (Loewenstein et al., 2001, 270).

4.2.6. Prototypes of uncertainty and a framework of ignorance

I will return to the emotional aspect of people's risk perception when discussing the affect heuristic in Section 4.2.7 as one explanation of how people do react to immediate unexpected information that might be caused by an nuclear accident like the most recent nuclear accident in Japan in 2011. I will now explain concepts that define prototypes and characteristics how people deal with uncertainty and, hence, create a predominant social ignorance structure. I then will explore uncertainty constructs that go beyond the standard explanation of probability. At the end, I will discuss results of cross-national studies and highlight additional aspects that help to reflect inherent biases Western research traditions on uncertainty might have.

Smithson identifies three traditional orientations in psychology that deal with people's evaluation of uncertainty or the unknown (Smithson, 2008, 206-207). The first tradition or prototype he entitles the "knowledge seeker." The knowledge seeker is seen as constantly seeking out new information and experiences, and assumes prior beliefs need to be updated as part of a learning process. This prototype of person tolerates uncertainty and is able to accept ignorance, at least in the short run, to obtain additional information. Knowledge seekers are open to new forms of communication, and they communicate and share their views fully and honestly. In his open and closed mind theory, Rokeach (1960) describes authoritarian people as intolerant of ambiguity, intolerant to multiple and heterogeneous ideas and beliefs, and against deviations from the ideological, religious or political, dogmas. Open minded people, however, are open to counter evidence and ambiguity, perceive unfamiliar information freely, exchange and listen to new ideas and are open to change (Smithson, 2008, 212). In the aftermaths of World War II Rokeach (1960) developed a bipolar typography comparing a 'gestalt type', who needs to know and understand and a 'psychoanalytic type' who is characterized by defending itself against threatening aspects influencing reality.[28] He observed that gestalt types, compared to psychoanalytic types, are less authoritarian and less prejudiced, tend to avoid religious dogmatism, are better at problem-solving, politically progressive and more appreciative to art and its merits.

The second tradition, characterizes people as seeking to reduce uncertainty. Smithson calls this tradition "certainty maximizer" (Smithson, 2008, 206). From this line of thoughts, (e.g., Mandler 1984; Izard 1991) uncertainty has a negative impact on one's emotional state. Uncertainty is assumed to cause fear and intense anxieties. Gudykunst and Nishida (2001) go even further to claim that anxieties can be interpreted as the emotional equivalent to perceived and externally induced uncertainty. Comparing both traditions, Smithson concludes that there is a "natural tension" between the prototypes of certainty maximizer and of knowledge seeker (Smithson, 2008, 206). I will return to this conflicting traditions of how people deal with uncertainty when discussing different prac-

[28] Rokeach's research was inspired by the desire to understand right-wing-authoritarianism and is in the tradition of a broad field on research on the authoritarian personality, such as earlier study by Adorno and colleagues (Adorno et al., 1950).

tices of risk assessments in Section 9. I assume that an authoritarian approach of solving risks is displayed in a linear and problem controlling approach of risk assessment, based on military order structures, whereas approaches in the tradition of knowledge seeking and openness to change might emphasize the importance of uncertainty to understand the deeper meanings of a threatening nature's problem.

The third decision making prototype in cognitive psychology is called the "intuitive statistician-economist" (Smithson, 2008, 206). This normative viewpoint on how humans reflect information and make decisions has a lot in common with decision models in the tradition of neoclassical economics. The underlying assumptions are based on probability theory and a perception of humans as hedonistic beings and utility maximizers who avoid pain and seek pleasure. With these assumptions, a model can be derived that explains how people maximize their subjective expected utility. The probabilistic part in this model is the assumption that humans are able to quantify and transform their perceived uncertainty about a state of the world into one single numerical estimate. The number is cognitively derived according to the principles of probability theory. The second assumption, the assumption on a hedonistic seeking human nature, or hedonistic preference structure, assumes that decision-makers are able to quantify different options or outcomes of perceived states of the world as utilities, based on a numeric calculation of benefits and costs. After the calculus of utilities humans are able to order their preferences. The expected utility number is the combination of the assigned probabilities and the number of the utility calculus. The highest expected utility number is the one humans will prefer because it is maximizing their subjective expected utility. That is one assumed process how humans quantify their decisions rationally.

In their discussion on the rational action framework (RAF), Rosa and colleagues (2014, 53) point out that in many empirically observed social processes the assumption of a quantifying and utility maximizing rational actor cannot be met. They furthermore observe in the scientific world, that the basic assumptions of the rational actor paradigm have been modified with additional ad hoc assumptions. They conclude that the ad hoc adjustment of the underlying assumptions indicates a weakness of the theory and, following Kuhn's (1970) idea of scientific paradigms, might not lead to a collapse of the theory but to an integration into another broader scientific paradigm (Rosa et al., 2014, 67). The authors emphasize that, especially regarding the process of risk evaluation, the basic assumption that human's decision making processes can be modeled as a process of optimization and maximization does not hold. They claim that social actions are determined and constraint by other human's actions or structural conditions of the environment. In this sense the relationship between humans and humans and humans and their environment defines the logic of the decision making process: "Most individuals are not able to calculate the likely impacts of their own choices in situations where many actors are likely to interfere and structural conditions are likely to change constantly" (Rosa et al., 2014, 67). Rosa and colleagues, inspired by Naomi Klein (2007), have sharp words for proponents of the rational actor paradigm implying that RAF's theorists prefer to empty the bathtub they are in, than to leave the wrecked ship: "many RAF theorists have become ardent proponents of changing the world in the direction of the model rather than adjusting the model in the direction of the world" (Rosa et al., 2014, 67). In complex social environments, in space and time unites, optimization processes are not leading to efficient and satisfying outcomes for every actor but are able, as I assume, to create unwanted conflicts among the actors and hence more risk to the whole entity.

At this point I feel it is useful to discuss different concepts and principles of uncertainty. The psychologist's assumption is that even though there might be objective uncertainties the field of interests are subjective (Smithson, 2008, 207). The dominant approach in risk evaluation is the assumption that uncertainty can best be modeled and depict in objective numbers derived from the principles and axiomatics of probability theory. From this perspective the concept of probability and its underlying logic of randomness is treated as uncertainty. The concept of randomness and probability is based on a situation seen as a game of chances, like in a casino[29], and the normative assumption is that people are maximizing their subjectively expected utility (Edwards, 1954, 381).

In psychological research, a second construct of uncertainty is the effect of delayed outcomes and consequences of individual actions (Smithson, 2008, 207). Outcomes that happen sooner are perceived to have a larger magnitude. In that sense, humans desire good outcomes and want them to happen sooner; in contrast, bad outcomes are perceived more worthy the sooner they are expected to happen. As a consequence, delayed outcomes are perceived to be uncertain. Certain outcomes are outcomes happening in the present moment. Decision theory that is taking the effect of delay or time into consideration predicts that people will behave risk averse for delayed gains and risk seeking for delayed losses in the future (e.g., Kahneman and Tversky, 1979; for an overview see also Frederick et al., 2002).

Smithson presents a third construct of uncertainty he calls "absence or lack of clarity in information" (Smithson, 2008, 208). In an environment with of imprecise or no information, probabilities cannot be derived. This field of research is broad and terminologies like ambiguity, vagueness, incomplete information, and non-specificity are used in a quite unstructured way to describe the lack of precise or sufficient information in the decision making process. Uncertainty in the meaning of absence or lack of information, a-priori or after empirical investigation, can be compared to Knight's strict meaning of uncertainty as discussed above (Knight, 1921, 231). This construct of uncertainty is also inspired by Keynes' thoughts on probability or the absence of probabilities in a social environment (Keynes, 1921).

In his experiment on betting on outcomes with known probabilities or ambiguous information (if probabilities are not known), Daniel Ellsberg tries to find an answer

[29] An illuminated casino in Monte Carlo, guests are coming, watching each other curiously; you can feel the dense and concentrated atmosphere in the space of hope and desire; you are sitting next to a silent gentlemen who orders a Martini without ice; you decide to ask for his name: "You can call me Mr. Uncertainty, Random Uncertainty." A new adventure to save the world begins – you and all your decisions are part of it.

to the question: "[a]re there uncertainties that are not risks?" (Ellsberg, 1961, 643). He can demonstrate in what has became known as the Ellsberg paradox (see for a more detailed discussion on the Ellsberg paradox Camerer and Weber, 1992) that people prefer a choice situation with uncertain probabilities over the option of known probabilities. From the axioms of decision making people should have either no preference or should rather prefer the known situation, 'the devil they know', than the unknown situation, 'to buy a pig in a poke'. Ellsberg points out that his results are not random but willingly wanted, that people's choices are an "operation of definite normative criteria" (Ellsberg, 1961, 656-657). He even asked people perceived as experts and familiar to probabilistic reasoning about their behavior. He concludes that people deliberately chose the option and wanted to make the decision, even though they know they are violating the criteria of subjective expected utility: "Yet the choices themselves do not appear to be careless or random. They are persistent, reportedly deliberate, and they seem to predominate empirically; many of the people who take them are eminently reasonable, and they insist that they *want* to behave this way, even though they may be generally respectful of the Savage axioms" (Ellsberg, 1961, 656).

In his book 'Ignorance and Uncertainty' Smithson (1989) introduces a more elaborate concept of ignorance of how people and social groups organize non knowledge. He differentiates between different levels and kinds of ignorance. The most obvious distinction of different levels of ignorance is "conscious ignorance" or the fact that we "know that we do not know", and "meta-ignorance", the fact that we "do not know that we do not know" (Smithson, 2008, 208). I introduced the idea of ignorance mentioned by Aven and Renn (2009, 9) above when discussing how to define risk (see Section 2.4.3). Smithson states that the language we use, e.g., English, has developed a language designed to rather eliminate ignorance by emphasizing the ability to express knowledge claims and state facts of the world, than to enunciate ignorance. Same he claims is true for the scientific community where the awareness of ignorance is a neglected and not well established field. He remarks that there is no accepted science of non-knowledge, such as a "Sociology of Nonknowledge" (Smithson, 1989, 2).

Smithson's taxonomy on ignorance embeds uncertainty, with its elements such as probability, ambiguity, and vagueness[30] in a broader concept of ignorance. For an overview of his taxonomy of ignorance see Figure 7. He argues that ignorance, as well as knowledge is socially created and depend on the position of a social group or of an individual. Knowledge as well as ignorance therefore is an object of social negotiation (Smithson, 1989, 6). Any social system by constructing its reality depending on different viewpoints is on the one hand producing anomalies, deviant information that does not match the existing viewpoints or social skills to communicatively integrate them into an existing system of beliefs, and on the other hand strategies defending the existing viewpoints. In Smithson's words, ignorance is a strategy to deal with "anomalies and other threats to established cognitive order" (Smithson, 1989, 7). From my point of view, Smithson takes a thoughtful angle when introducing his concept of ignorance. A perspective that

[30] Vagueness includes fuzziness and nonspecificity.

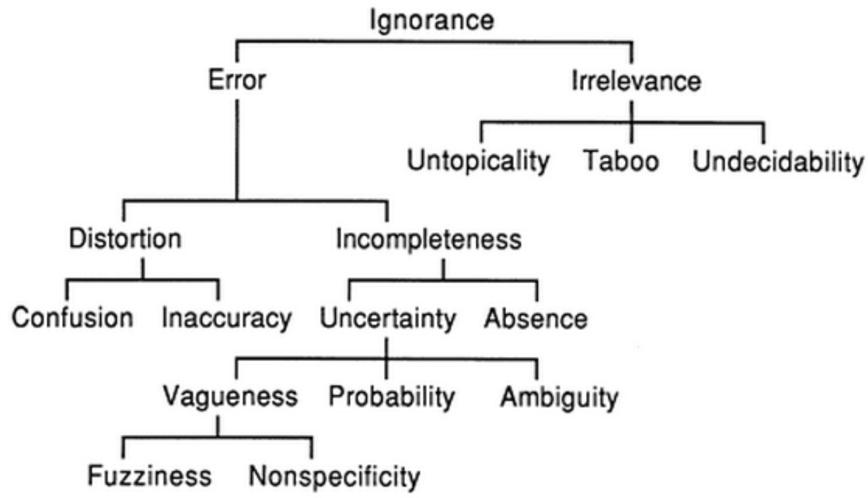


Figure 1.1. Taxonomy of Ignorance

(Source: Smithson, 1989, 9, Fig. 1.1.)

Figure 7: Smithson's taxonomy of ignorance.

is directing a reader's curiosity to a broader space opening one's mind to carefully reflect on the meaning of non knowledge.

The author's starting point of reflection is to find a distinction of how society has created a socially accepted practice to cope with anomalies. Ignorance, Smithson claims, is constituted in part of error and in part of irrelevance. He starts with an example of everyday language and the distinction between the active voice of 'ignoring' and the passive voice of 'being ignorant'. 'Ignoring' is an active social state of deliberately paying inattention to an object or situation, or purposely not looking at something. Ignoring as an active act is a "declaration of irrelevance" (Smithson, 1989, 7), in his taxonomy called 'irrelevance'. 'Being ignorant' to the contrary implies a passive social state that is based on distortion or incomplete knowledge. Ignoring as a state is "an erroneous cognitive state" (Smithson, 1989, 7), in his taxonomy called 'error'.

Separating irrelevant and erroneous views, as two different perspectives of reality, has different implications for a socially perceived reality. The first strategy of ignoring is a way of excluding conflicting information denying their existence. The second strategy of being ignored implies an inclusive strategy for coping with conflicting information. The strategy to declare anomalies as irrelevant is a negative way to ignore them and results in banishing them from reality (see Figure 7). Fields of banished information are 'utopicality', to declare something as folk wisdom, 'taboos', socially enforced irrelevance, or 'undecidability', declaring words as fantasy and fiction (Smithson, 1989, 8).

An erroneous view on the contrary allows the observer to enter a space of anomalies, a space that is not able to be perceived consciously. This framework of reality is open to new information and therefore an inclusive strategy, open for changes in reality. According to Smithson 'error' itself is divided in 'distortion' and 'incompleteness'. Distortion in degree, like a systematic error or bias, Smithson terms 'inaccuracy' (I've always done it like this, I cannot explain the accident.). Distortion in kind, like a wrongful substitution, he calls 'confusion' (Hups, that was the wrong button I pressed - sorry for the accident.). Error termed as incompleteness is called 'absence' in its kind (That was a complete new situation – the neutrons started to sing Elvis Presley songs and the protective cover started to laugh and cracked up, we sincerely regret the accident.) or error in degree, termed 'uncertainty'. As above mentioned uncertainty includes terminologies like probability, ambiguity or vagueness (There was a tiny probability left, a number of many zeros and a one at the end we could not exclude from our calculations, it was a random accident.) (Smithson, 1989, 7-8; Smithson, 2008, 208).

In my point of view, Smithson's taxonomy and its different levels and kinds of ignorance, offers a picture of the term risk perception in its whole nature, including the beauty of ignorance. Ignorance, and risk perception as part of it, is a dynamic and opens up new spaces for reasoning and thinking. I perceive risk perception as one, out of many, indicators to direct attention to tendencies and developments of distortion or irrelevance, tendencies that systematically, purposefully, unintentionally, or randomly exist in society. Allowing individuals to express their opinions about risks indicates the manifold facets of ignorance and non knowledge.

Smithson's concept is not static but assumes that social systems interact with each other. Smithson (1989, 8-9)[31], refers to Mary Douglas (1973) and her interpretation of taboos as socially enforced irrelevance. Irrelevance in the sense of taboos is a devise to create rules that define parts of the social life as relevant and vice versa irrelevant. Active ignoring, socially allowed ignoring, in that sense, creates safety. Historical examples of the 20th century are the Holocaust and the nuclear bombing of Japan in World War II, both acts of active ignoring (covered in taboos) that cannot be kept under the cover of silence and are a key element to open the space for new controversy because history needs to be covered in a story (Curthoys, 2008).[32] What seems obvious in the world of historical knowledge also applies to the world of scientific knowledge and its taboos. Douglas (1973, 100-101) describes science as a system that is cognitively ordering its environment and is, hence, producing anomalies. As any socially constructed culture, science also needs to defend its defined space by confronting the anomalies with appropriate strategies of defense. Douglas points to the Western intellectual culture and highlights the sophisticated normative paradigms, such as probability or decision making theory as such a defense strategy. Smithson also states that the Western intellectual culture is a strategy of exclusion, a social practice of actively ignoring other forms of knowledge that are not based on the scientific paradigms and principles; realities that

[31] See also Bammer et al. (2008).

[32] An oppressed and slaughtered history of human history cannot be sealed for long – slaughtered and oppressed souls find their way back in in the glamourous stories of modern history.

are ignored or tabooed by the principles of logic, mathematics, or any other forms of accepted forms of reasoning (Smithson, 1989, 8-9).

Society's interplay of ignoring and being ignored seems to me a fruitful process to discover densities in humanity's spaces of interaction. Gaps between experts' and laypeople's perception of risk or cross-cultural differences in society's risk perceptions might be a suitable indicator to locate dense spots of human interaction. Research on risk perception might help to detect those ideological blind spots and sealed spaces of social interaction. Philip Tetlock (2002) discusses a broader framework of uncertainty. He assumes that people intuitively react different to uncertainty depending on their deeper motivation to act. He describes five different prototypes that deal with uncertainty.

The 'intuitive scientist' seeks the truth. An 'intuitive economist', his second character, seeks utilitarianism and acts in accordance with this purpose. Also the metaphor of an 'intuitive politicians' (coping with accountability demands), of an 'intuitive prosecutor' (trying to enforce social norms), and of an 'intuitive theologist' (protecting sacred values) enters the space of decision-making procedures in uncertainty. Tetlock explains conflicts that for instance, the scientific perspective of seeking the truth might not be appropriate or functional from a theologist's perspective, who defends his or her God from being erased by scientific logics of reasoning. Tetlock also detects the defense mechanisms of not accepting one another's rules of accountability, as the primary challenge of risk management and risk communication (compare Smithson, 2008, 208). Tetlock's (2002, 468) proposed framework of "functionalist pluralism" is an approach of mixed metaphors, maybe confusing at the beginning but necessary for theory building. His aim is to open the social space for mutual understanding of the other, concluding: "The looming challenge will be to develop viable mixed-metaphor models of how people resolve conflicts among functionalist imperatives" (Tetlock, 2002, 468). He claims for mixed typologies, observing that cross-functional conflicts arise when people's primary functionality, such as the scientific demand for seeking truth, is crossing a boarder of a deeper basic functionality. For example someone realized that by seeking the truth his or her work is only to polish career and to 'create' results. Or somebody hurts someone and realizes a conflict with his or her ethic value system. Tetlock's interpretation of cross-functionalist conflicts is "[t]he general theme seems to be cybernetic: People discover they have enough of a functionalist mind-set only after they have had more than enough" (Tetlock, 2002, 468). His proposal for an "integrative agenda" will not solve the "battle for explanatory primacy" (Tetlock, 2002, 468) but such a framework could structure the discussion and lead it into a direction where extreme positions are recognized not as anomalies of a system, but as a starting point of communication. Multiple and conflicting viewpoints are the core of an integrative framework.

For my concept of a risk entrepreneur, Tetlock's advice is to keep a functionalist pluralism's mind: "Functionalist pluralism model the mind as a polyglot polity populated by semiautonomous functional fiefdoms, each with its own operating principles, in uneasy coexistence. They tend to be suspicious of monistic proposals, such as Greenwald's (1980) totalitarian ego, viewing them as special cases in which a particular set of functions – those stressing cognitive order, continuity, and self-image protection – have achieved self-regulatory primacy" (Tetlock, 2002, 468).[33] This "self-regulatory primacy" seems to be the need for certainty in a world of uncertainty. The risk entrepreneur as prototype balances the needs of certainty and uncertainty independent of a functional framework or changing social environment. In that sense the risk entrepreneur provides a space of certainty and uncertainty for extreme functional views of a certainty seeker and an uncertainty seeker. Certainty in this sense is not an immovable and desirable state of the world, the holy grail o knowledge, anymore, uncertainty on the other hand leaves its connotation of a mystical myth and can be integrated in the social discourse as a complex state of an intrinsic open world and a place for potentially new and creative solutions, such as Afifi and Weiner (2004) suggest in their framework of interpersonal communication.

Functionalist pluralism and the pluralist's demand of being "suspicious of monistic proposals," as mentioned above, does not stop at national or cultural boarders as research by Nisbett and colleagues (2001) indicates. The Western worldview of a dualistic true-false logic, oriented to categorize reality by artificially defining boundaries of distinction has been questioned in cross-cultural research. It seems that people for example in Asians, on average, tend to be more oriented towards seeking relationships and similarities between objects, perceiving oneself as part of the whole entity not one category, whereas Westerner try to identify objects, categories and rules to order objects in categories and to identify themselves as member of a category.

Reflecting the debate of risk perception an important aspect is that the corresponding view on uncertainty and its tradition of perceiving uncertainty as probability is ideological biased and culturally Western. The risk entrepreneur crosses cultural boarders and acknowledges the space of the excluded middle, the contradiction, from a Western perspective (see Smithson, 2008, 214), that a proposition if not true, does not need to be false. An either true nor untrue state is permitted and can be accessed if necessary in the debate of risk environments, thanks to a wider understanding of uncertainty and ignorance as outlined above.

For empirical risk research, one can conclude that people who are asked to evaluate a risk's perceived danger, such as the danger of nuclear power, uncertainty might be expressed as a tendency to choose a 'neither nor' perspective rather than a more extreme statement of approval or rejection of a danger's risk. The sources of uncertainty are many fold as Smithson points out in his work (Smithson, 1989, 2008). Uncertainty can be expressed in strategies of irrelevance, like taboos expressed in defensive rejection of a danger or hidden behind a historically created curtain of innocence, guilt or shame. Furthermore strategies of irrelevance like undesidability, expressed in a 'nor true nor false' expression of risk perception shape a society's coping strategies with uncertainty. The complex and ambiguous nature of a low-probability high-consequence risk, like nuclear power, might also result in judgements based on error and its many faces

[33] Tetlock refers to Greenwald's (1980) paper on the totalitarian ego.

like confusion, inaccuracy, and uncertainty because of lacking empirical evidence and contradictory information. From Tetlock's (2002) pluralistic view, conflicts between different perspectives exist. Different sets of functions exist in a society like the metaphor of the intuitive scientist, seeking truth and transparency or the metaphor of the intuitive politician seeking for accountability, rhetoric, and secrecy. The pluralism of mind-sets might already exist in a person's judgement of risk. In this sense, risk perception is already an expression of a personal conflict. Reflecting the multifaceted nature of individual risk judgement, measured risk evaluation is a vague concept in terms of its explanatory power, and scientifically accepted concepts of accuracy. The reasons that are guiding a mind to evaluate a risk are manifold opening a wide space for conflicting interpretations, almost purposefully rejecting to be captured in the concept of causal inference and scientific reasoning. I will come back to explanatory factors of nuclear risk perception when discussing empirical research on cross-national comparison of nuclear risk perception in Section 5.

4.2.7. Affect heuristic

Before focusing on empirical research on nuclear risk perception, including cross-cultural or cross-national risk perception, I want to introduce two concepts of how new information, such as information of a nuclear accident, can alter individual's evaluation of risks, in my case the risk of nuclear power. An external shock, like a nuclear accident, can be assumed to be a source of information that is able to influence people's functional mind-set, their affective, as well as analytical system, creating an openness to reflect one's own perspective. The social reactions to the external shock might also be able to change the procedures and rituals how the actual social system is managing, regulating, and governing the risk. First, I want to discuss the concept of affect heuristic; secondly I want to discuss and introduce the framework of the social amplifications of risk.

As described in Loewenstein et al.'s risk as feelings hypothesis (Loewenstein et al., 2001), emotions are able to play a role in the evaluation of risks (compare Section 4.2.5). In the following part, I want to highlight the mechanisms and theoretical explanations on how underlying affect mechanisms interplay with more obvious or conscious rational and analytic mechanisms in people's decision making process. I will refer mostly to research on the affect heuristic by Paul Slovic, Melissa Finucane, Ellen Peters, and Donald G. MacGregor (Slovic et al., 2002, 2004, 2007; Slovic, 2010). Slovic and colleagues argue that affect is related to a consciously or unconsciously perceived feeling state, evoked by a positive or negative reaction to a stimulus. The mechanism is an intuitive judgement of a state as either good or bad. The affective judgement of a risk situation is happening rapidly and automatically, maybe without being noticed by a person. The authors argue that "reliance on such feelings can be characterized as "the affect heuristic"" (Slovic et al., 2004, 312).

Like the risk as feelings hypothesis or Antonio Damasio's above mentioned somatic marker hypothesis (Damasio, 1994), Slovic and colleagues emphasize the importance of an emotional system as a mode of reasoning and thinking. The intuitive judgement of a situation is an experiential mode of thinking. According to Seymour Epstein (Epstein, 1994; Epstein et al., 1992), there are two distinguishable modes of how people perceive reality. The first, he calls the "experiential mode", perceives reality intuitively, automatically, non-verbally, and narratively. The second mode, the "rational mode", is a deliberative, analytical, verbal, and rational state to perceive reality (Epstein, 1994, 710).

Each system is characterized by complementing aspects. Epstein and colleagues define twelve attributes characterizing each mode of thinking (Epstein et al., 1992, 329, Table 1):

According to the authors the experiential system is characterized as:

1. Holistic
2. Emotional: pleasure-pain oriented (what feels good)
3. Associationistic connections
4. More outcome oriented
5. Behavior mediated by "vibes" from past experience
6. Encodes reality in concrete images, metaphors, and narratives
7. More rapid processing: oriented toward immediate action
8. Slower to change: changes with repetitive or intense experience
9. More crudely differentiated: broad generalization gradient, categorical thinking
10. More crudely integrated: dissociative, organized into emotional complexes (cognitive-affective modules)
11. Experienced passively and preconsciously: we are sized by our emotions
12. Self evidence valid: "experiencing is believing"

In contrast, what Epstein and colleagues (1992, 329, Table 1) call the rational system is characterized as:

1. Analytic
2. Logical: reason oriented (what is sensible)
3. Cause-and-effect connections
4. More process oriented
5. Behavior mediated by conscious appraisal of events
6. Encodes reality in abstract symbols: words and numbers
7. Slower processing: oriented toward delayed action
8. Changes more rapidly: changes with speed of thought
9. More highly differentiated, dimensional thinking
10. More highly integrated
11. Experienced actively and consciously: we are in control of our thoughts
12. Requires justification via logic and evidence

Slovic and al. argue that both systems follow rational logics and, hence, they differentiate between the "experiential system" and the "analytic system" (Slovic et al., 2004, 313). They further argue that in the history of human evolution on earth the experiential system was the dominant mode of thinking, optimized to survive throughout evolution. With socialization and the evolutional change of humanity having more control over the environment, the analytical mode of thinking became the dominant force of human reasoning.[34] Slovic at al. (2004, 313) criticize the idea of a purified rational mind and its guises because of the dominant weight it gained in recent history, purposely separated from the emotional processes human reasoning actually is based on: "As life became more complex and humans gained more control over their environment, analytic tools were invented to "boost" the rationality of our experiential thinking. Subsequently, analytic thinking was placed on a pedestal and portrayed as the epitome of rationality. Affect and emotions were seen as interfering with reason."

The concept of two separated systems for human reasoning, the 'good' rational system and the 'bad' emotional system, is questioned by framework of the affect heuristic and empirical evidence on the effect of emotions on human reasoning. The affect heuristic is based on the assumption that "affect is essential to rational action" (Slovic et al., 2004, 314). And it is more. Finucane and colleagues describe the ongoing and permanent interaction of the experiential and the analytic mode as "the dance of affect and reason" (Finucane et al., 2003). Any rational decision based on analytic thinking is complemented or prepared by an emotional reaction or affective process. In line with Zajonc (1980), the authors are convinced that affective reactions provide guiding information and orienting mechanisms by reacting to stimuli. These reactions are an efficient way to deal with a complex and uncertain world. It is also an reaction to detect and avoid dangerous situations (Slovic et al., 2004, 313).

Damasio (1994) argues that affective reactions are caused by positive or negative images associated with present or future events. He explains that human thinking and reasoning is to a large extent made up of images, and positive or negative feelings that are associated, in his words "marked", by those images. These associations or markers are directly linked to somatic reactions perceived in the body. In that sense, the negative or positive feelings and its somatic reactions interact with the mind. Positive images or outcomes are liked with a pleasant sensation. Hence, the imagined or perceived situation is perceived as an object of incentive. Negative feelings, on the contrary, create an unpleasant bodily state and are perceived as an indicator of a dangerous situation. Damasio concludes that somatic markers improve the decision making process, leading to a more efficient outcome for the individual. His conclusion is based on empirical research on decision making, observing that people with limited ability to perceive somatic marker perform worse in the decision making procedure. The interplay of feelings and mental images might be a mechanism of biological regulation, developed through evolutional learning in human history; and might still be the guideline for effective human reasoning, Damasio hypothesizes (Damasio, 1994, xii).

The theoretical concept of the affect heuristic, as proposed by Slovic and colleagues (2007, 1335), is based on Damasio's assumption that stimulus images are marked by feelings, either positively or negatively. The authors furthermore assume that the degree differs to which images or representations of events are marked or tagged with affective

[34] The rational mind as the "juggernaut" of a new age as Giddens already portrait the dynamics of modernity (Giddens, 1990, 131).

emotions. Hence, the intensity of the marker differs with the stimulus image. Furthermore, it is hypothesized that an affect pool contains all the positive as well as negative markers that are associates either consciously or unconsciously with all perceived images. In the case of a judgement people intuitively refer to the affect pool and sense the intensity of a marker associates with the real or imagined image. Images are mapped in different ways due to the affective quality of a stimulus image; and the markers are also used in different ways, depending on the ability for an affective or rather analytical interpretation of a situation.

Given the complexity of affective mapping, it is obvious to assume that individual's affective reactions differ across individuals. It also has been shown that an individual's tendency to rely on experiential thinking varies across individuals (compare for example, Gasper and Clore, 1998). Beside individual differences in affectively tagging images and relying on the affect pool's information, the tasks as such differ. Different choice situations or stimuli images reveal different degrees of information and might not provide all attributes to map the images unequivocally: it might be the case, as Slovic and colleagues summarize, that "tasks differ regarding the evaluability (relative affective salience) of information" (Slovic et al., 2004, 314).

According to the proponents of affective heuristic, the guidance of affective reactions provide a readily available and effective process to judge complex as well as uncertain situations, even performing probability judgements: "Using an overall, readily available affective impression can be easier and more efficient than weighting the pros and cons of various reasons or retrieving relevant examples from memory, especially when the required judgement or decision is complex or mental resources are limited" (Slovic et al., 2004, 314). The above mentioned assumptions of a simplifying process – a mental short cut – based on affective, readily available information states lead to the conclusion that affect serves as a heuristic (Finucane et al., 2000a). The availability or representativeness heuristic (compare e.g., Tversky and Kahneman, 1973; Kahneman and Tversky, 1979) serves in a comparable way as a mental short cut using imaginability, memorability, and similarity as cues for probabilistic decision making. Slovic and colleagues even argue that the availability heuristic might be based on affect as well as on imaginability (Slovic et al., 2004, 317). They argue that memory images are tagged with affect and, hence, either positively or negatively associated with easily remembered information, resulting in more or less weight for risk judgement. Affect might therefore explain in part a bias observed by Tversky and Kahneman (1973) in people's probability and frequency judgement. As will be explained later in more detail Slovic et al. (2000b; 2007) find that a proportional representation of information expressed in probabilities or percentages is attributed with greater weight in judgement situations.

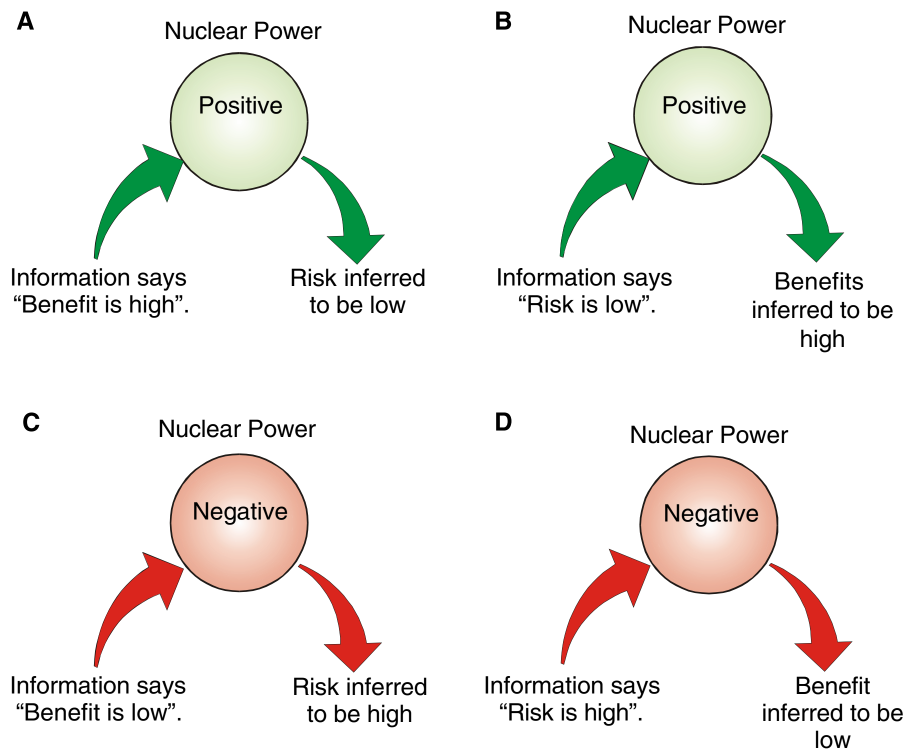
How can the affect heuristic and the experiential mode of judgement contribute to gain a better understanding of people's varying dimensions of individual risk judgements? The discussion of empirical results, mostly derived in experimental laboratory designs, might shield more light on the affective component on decision making. It might also explain why gaps between experts and laypeople are likely to observe. As mentioned discussing the psychometric paradigm (compare Section 4.2.2), research by the "Oregon Group"[35] showed that the acceptance of a risk is strongly correlated with the perceived dread of a hazard (Slovic, 1987; Fischhoff et al., 1978). It can be assumed that affective stimuli images are guiding the evaluation processes of a risk. Affect might even be, as Zajonc (1980) proposed, the dominant force in judging risks and benefits.

In a study by Alhakami and Slovic (1994), an inverse relationship between risk perception and a risk's benefit of an activity was observed. The inverse relationship means that lower risks perception correlates with higher perceived benefits of an activity. People were asked to rank an activity on a bipolar scale, such as good or bad, to map imposed negative or positive emotions on that activity. The strength of the emotional mapping was correlated to the inverse relationship of perceived risk and perceived benefits. The authors hypothesize about the interplay – or the 'dance' – of feelings, risks, and benefits that favorable feelings towards an activity are reducing perceived risks and are increasing perceived benefits. Vice versa, unfavorable feelings might result in judging an activity as riskier and less beneficial. The authors conclude that people's judgement of the activity does not only depend on how people analytically think of an activity and its outcomes but to a great degree also on how people affectively perceive the activity and its potential outcomes.

Further research by Finucane and colleagues (2000a) tests the affect heuristic and its assumption that affect acts as a confounding factor in risk and benefit judgements. Manipulating the stimuli image, by providing additional positive or negative information of the risk or benefits of an activity should result in a corresponding inverse judgement of the associated factors, the authors hypothesize. For example, if additional negative information of an activity's risks is provided, the perceived benefits of that specific activity should decrease. Accordingly, if an activity is described as beneficial the additional information should result in a lower risk perception. See Figure 8 for an exemplified illustration of the above hypothesized relationships. In their study Finucane et al. tested people's risk and benefit judgements of nuclear power. By providing additional information of the technology's benefits people judged the perceived risks lower; and providing additional information about nuclear technology's risks resulted in a decrease of perceived benefits. In an additional study under the experimental condition of time pressure, this inverse relationship, influenced by the information provided, increased greatly. The authors conclude, that affect is influencing to a varying degree the judgement of perceived risks and benefits and becomes more obvious when the time to think and to use the analytical system is reduced. Hence, risk judgements are not only a process of deliberative thinking but also process of affectively perceived experience (Slovic et al., 2004, 315).

For my research on nuclear risk perception the theoretical approach as well as the empirical results on the affect heuristic seem to emphasize the importance of emotional

[35] Renn and Rohrmann (2000, 17) call Slovic and colleagues' research group on risk perception, respectfully the "Oregon Group."



(Source: Slovic et al., 2007, 1343)

Figure 8: Illustration of affect heuristic (example risk perception of nuclear power).

reasoning. If the theoretical assumption of the analytical and the affective system cannot be rejected, it might be the case, on one hand, that affective processes are directing or even steering, at least to some varying degree controlling, the analytical or rational processes in risk evaluation's decision making procedures. The affective mapping of images can be assumed, to different degrees, for experts as well as for laypeople. I also conclude that a technology's negative stimuli images are creating strong affective reactions, for both laypeople and experts. Due to the inverse relationship of risk and benefits, the affective laden negative images in the past, like the images of Hiroshima, nuclear tests or the accident of Chernobyl, are reducing the perceived benefit and hence are increasing the perceived risk of nuclear technology.[36] I hypothesize that experts'

[36] In the language of Bayesian updating, the a-priori estimate of a technology's risk is not only based on the amount of information and the analytical processing of the information, but also on the affective mapping of stimuli images that are associated with a technology. Additional empirical evidence of a new accident is updating the a-priori evaluation of nuclear technology. The sudden shock of an accident is putting additional affective weight on the a-posteriori evaluation, decreasing the ambiguity or uncertainty of the evaluation. Hence the density of a new estimator of a technology's risks has a credibility interval that is more narrow compared to the a-priori estimator's credibility interval. I hypothesize that the likelihood as well as the certainty estimation of a negative future

affective images are more driven by numbers and statistics, as well as on past experience as a technocratic risk manager. As a consequence their experiential system reacts in the opposite way. From an technocratic perspective a negative image of nuclear war or an accident is a motivation to improve the technology and perform even better in the future. This could mean negative examples are decreasing the risk and are increasing the benefits for an experts' experiential as well as analytic system.

The second conclusion I draw from research on the affect heuristic is based on the amplifying force of a sudden change. I assume that an sudden nuclear accident like the accident in Fukushima can be interpreted as an incidence that created time pressure on people's risk evaluating strategies. If time pressure is blocking analytic deliberation the emotional processes are interplaying in the risk-benefit evaluation. The negative images of an accident might create a sudden increase in laypeople's risk perception. It might be the case that experts' reaction under time pressure will have the opposite effect. Defending their positive pool of images their dance of risk evaluation highlights the benefits, protecting the individual's believe system to concede victory to empirical evidence.

Epstein's (1994) and Loewenstein et al.'s (2001) as well as the affect heuristic theories (e.g., Slovic et al., 2004) of dual processing of information also explain how people process probabilistic information and how that process is related to affective mechanisms. The experiential system, as characterized by Epstein and colleagues (1992, 329, Table 1) and shown above, perceives reality through experienced information stored through images or narratives. The information is connected and laden with feelings. The experiential system is trained for rapid processing and immediate grasping of information and to translate information in broader, narrative categories, in its extreme case in the bipolar narrative of good and bad. It changes slower and changes are based on perceived evidence. The rational or analytical system functions by seeking for cause-and-effect circumstances that can be processed according to logical rules and evidence. The language to describe reality is a coded language of abstract symbols for both words and numbers. Analytic thinking, using a symbolic language, can create its own multi-dimensional reality. Reality can change by definition: safe is what is defined as safe according to the rule of the master-minds of safety.[37] Symbols like numbers help to generate safety, hence

outcome, e.g., the likelihood of a new accident, will be increased by additional information of a sudden accident. Resulting in an increase in risk perception. The change depends on the a-priori deliberative and affective information processing as well as on the effect of affective reactions when new information is provided to update the a-priori evaluation. Because of the affective mapping of the new information, the change in risk perception might be permanent and hardly changed by additional beneficial information of the technology. It might also be the case that because of conscious or unconscious affective mapping of new information, the sudden shift in risk perception might decrease again. However even when risk perception decreases to the basal level, the images stored in the affective pool can be reactivated as in the case of a new accident and might result in an even greater amplified reaction due to the combination of new and stored affect-laden information.

[37] For example: the discussion of the question of the optimal balance of risks and benefits and the acceptability of a risk started with Chauncey Starr's approach to use economic data like fatality or income statistics to generate a measure for the acceptable tradeoff of risk and benefits (Starr,

what is safe also depends on the symbols that can be analytically associated with the definition of safety. Realities that cannot be encoded in symbolic language cannot be treated as relevant information – it cannot even be traced – this information does not exist in this particular information processing mode.

Studies on the symbolic representation of numbers, as for example a study by Slovic and colleagues (2000b), show that risks expressed as probabilities were perceived as less dangerous, compared to the representation format of risks as relative frequency. It seems that the enumerator containing the actual cases, like number of nuclear accidents or the number of people dying after being infected by a disease $(\frac{\text{number of accidents}}{X})$, creates affect-laden images, independent of the size of the population at risk, the number of the denominator: $(\frac{X}{\text{population at risk}})$. That image is stronger than an image evoked by an abstract proportional number, like a probability, a relative frequency that had been transformed and standardized according to rules of scientific logic. It seems to me that the narrative rules to transform or describe information seem to influence the risk evaluation process.

The language in which a risk is presented seems to have an decisive impact on how people judge risks. A study by Hendrickx et al. (1989) examines the effect of different representation formats of a technology's safety. In an experimental study, information was presented in a number format using relative frequencies or in a narrative format, as an accident scenario. Both formats influence people's risk judgement. It turned out that narrative factors, like the cognitive availability of a scenario and quality aspects like personal control, are more effective to create an affect-laden image of a risk. It might be the case that the combination of affect-laden narrative representation of a risk, for example through media coverage, and the tendency to rely on the mere number of events in terms of relative frequencies instead of transforming the information into a complex standardized number like a probability, that the combination of both information processes lead to people's tendency to overestimate a risks frequency, as observed for example by Lichtenstein et al. (1978).[38] I conclude that the observed risk judgement is, at least to some degree, a combination of the availability heuristic and the affect heuristic that lead to emotionally weighted available information.

Research on risk judgements and the effect of affect-laden images reveals that the representation of information in probabilities, i.e. a proportion, weights more in a decision making process than the corresponding outcome information in terms of losses, expressed in units. Studies by Bateman and colleagues (2007) on the attractiveness of gambling situations state that the attractiveness of a gamble was more sensitive to

1969). Fischoff and colleagues (1978) introduced an alternative approach using psychometric analysis deriving to the conclusion that perceived risks are higher than the risks levels that had been defined as acceptable by the approach Starr suggested. Consequently, they question the analytic process, especially the information used to generate safety-measures, used by regulation agencies to justify a technology's safety for society.

[38] For critical comments on the research design and the accuracy of the term bias see the comment of Shanteau (1978).

changes in the probability of winning than to changes of monetary losses. Affective mapping might be an explanation of these dominance of proportions or probabilities. Probabilities are easy to map and compare because they have a constructed 'natural' upper and lower bound. Losses expressed in unit outcomes like money or fatalities do not have a reference scale. To map an image or information into an affective category like good or bad or attractive and unattractive a diffuse scale with unlimited units like the amount of a currency (e.g., 100 USD) or number of fatalities (e.g., 150 people) does not reveal enough information to map an image precisely. Studies on life saving indicate similar results (e.g., Fetherstonhaugh et al., 1997; Baron, 1997).

Given the assumption that symbolized numbers, like probabilities, weight more than symbolized numbers of outcomes like units of fatalities, it might be the the case, as I hypothesize, that both numbers should not get mixed together because of the difference in meaning they bear. My ad-hoc hypothesis in case of nuclear risk perception is that experts' dominance of the analytical encoding of information is guiding an (prototype) experts' mind towards the small probability of an accident. In line with the theoretical encoding of reality an expert is interpreting the small probability as impossibilities. The actual numbers of an outcome are perceived as not relevant, because the probabilities are encoding and therefore diminishing the already symbolic number of a natural number (a nonnegative integer ($\mathbb{N}_0$) like 0 1 2 3) to an even different encoding system of complex number like the rational numbers ($\mathbb{Q}$). Rational numbers allow for numbers in the range between 0 and 1.[39] Through symbolic encoding the numbers are not affective laden anymore. It might be the case, a second ad-hoc hypothesis, that the process of symbolic encoding is an highly affective process. It means that the art of encoding according to the rules of probability theory is an emotionally process related to positive outcomes and, hence, mapped in the affect pool as positive. In this emotional process of encoding, the quality of the initial information, the historical narratives and the assumptions behind the encoding process are getting neglected in the procedure to derive the final number.

The analytical mode needs the reality as numbers, to communicate and to tell a story based on numbers; whereas the experiential mode needs the reality translated in feelings to be able to communicate and to tell a story based on feeling. Both processes, I conclude, are more or less complex heuristics to understand life and make decisions in a natural environment.

For laypeople's judgment of risks it is important to notice that probabilities might be perceived not gradually, but more or less categorically. Laypeople's encoding can be assumed to be a rough encoding, giving more weight to the affectively perceived outcomes. Such categorical perception is based on the notion of possible versus not-possible. The categorization process might be stronger in uncertain situation and when highly emotionally mapped images such as images of a disaster are available. If the consequences are perceived as very positive or extremely negative, the affective mode reacts more sensitive to the possibility of an event rather that to the probability or

[39] Even more complex encodings of reality is allowed in the classes of real numbers ($\mathbb{R}$).

likelihood of an event (Slovic et al., 2004, 318). In that sense very small probabilities, like the probability of a nuclear accident are getting great weight, independent on the symbolic coding of the derived likelihood of an accident and independent of additional (positive) information of the hazard's source. Rottenstreich and Hsee (2001) demonstrate in an gambling experiment that if a gamble's potential outcome is perceived as very emotional, an affect-rich outcome, the attractiveness of a gamble is getting quite insensitive to probability changes. Which means, technically speaking, that the assumed non-linear S-shaped weighting function is getting more extreme if a lottery is involving affect-rich outcomes and less S-shaped, hence, more linear, if the outcome is affect-poor (Rottenstreich and Hsee, 2001, 186, Figure 1).

Slovic and colleagues (2004, 319) point out that the experiential system, based on the categorical encoding, does encode numbers in a non-linear way, that can be perceived as a bias. The authors observe that the affective system regards small changes as important as in the way that ego wants to save one life if ego sees alter suffering. The system does not multiply the emotions to any degree becoming indifferent when the numbers of people suffering are getting into thousands and millions, the system is not designed to calculate feelings according to the rules of math. There is bias in "psychologic numbering" (Fetherstonhaugh et al., 1997) guiding the experiential system in decision making processes. Slovic et al. (2004, 319) emphasize that the experiential system is able to send misguiding information.[40]

Slovic et al. see their concept of the affect heuristic as a contribution to risk management, especially towards the question how the complex interplay of affective and rational reasoning can be used to lead to sustainable risk management. They ask: "Now that we are beginning to understand the complex interplay between emotion, affect, and reason that is wired into the human brain and essential to rational behavior, the challenge before us is to think creatively about what this means for managing risk. On the on hand, how do we apply reason to temper the strong emotions engendered by some risk events? On the other hand, how do we infuse needed "doses of feeling" into circumstances where

[40] Aside: I am not so sure if 'misguiding' is the right term. If the world is linear there is a bias. In a nonlinear world, there is no bias and hence no misguidance. It depends on the point of view of the observer and the assumptions that defined the 'mis-' in the guidance part. I assume, that what is called the 'mis-' can only be proved by history and future's reality and not by present interpretation of reality and its normative assumptions on human behavior. Therefore, I would suggest not to speak of misguidance of the experiential system. I would suggest to use a neutral term, such as 'listening' or 'consulting'. I also would suggest to see the individual as the active part in the communication process with both systems. Not systems are communicating with the individual, but individuals are communicating with their systems – consciously or unconsciously. People are listening with varying degrees of awareness to the languages of their experiential and analytical system and the information the languages provide. People then decide (conscious or unconscious) to use the information to decide to act. These processes are influenced by different kinds and levels of ignorance as shown by Smithson (1989). In that sense there is no misguiding or misleading strategy, but different ways to react to reality and encode the information into different languages. It also means that there is no faulty judgement but only different judgements – my world is an empirical and not a normative world.

lack of experience may otherwise leave us too "coldly rational?"" (Slovic et al., 2004, 319). As answers to their questions, the authors underscore the distinction between decision utility and experience utility (compare e.g., Kahneman, 1994; Kahneman and Snell, 1992). According to behavioral decision theories, time is the factor that proves if the decision utility is constant and not changing with more experience. A decision's utility might differ greatly after a certain time. The ability to constantly monitor decision's utility enables societies to learn from experience and to react to past decisions. In this sense, decisions are not a gamble anymore and uncertainty not an object to control but a factor to understand for it contains the information that we need to improve life on earth. The meaning of affect in this process is an important factor because it is an indicator for change. I assert that humans cannot control emotions with the techniques of ignorance, whereas you can control theoretical assumptions, based on rules, through the techniques of ignorance. In that sense Slovic and colleagues conclude "[...] the affect heuristic enables us to be rational actors in many important situations. But not in all situations. It works beautifully when our experience enables us to anticipate of our decisions. It fails miserably when the consequences turn out to be much different in character than we anticipated" (Slovic et al., 2004, 319). In this sense it is more than reasonable, I boldly conclude, that the experiment of nuclear power, based on no experience, was an affective decision: 'it was the time to do it.' The empirical evidence is showing that the idea of nuclear power is too dangerous for future life on earth, which may be proved with more experience. It is time to react and use the analytical, as well as the affective mind, to find a solution to manage the risk of nuclear power in the future.

I want to summarize the part on the affect heuristic by pointing out the most important aspects for my research on nuclear risk perception. I think a crucial aspect is the assumption that there are many functional systems of human reasoning. From the scientific perspective it is assumed that there are two systems: the experiential system and the analytical or rational system. It is assumed that experiential knowledge is the underlying knowledge system in any judgement processes, no matter to what degree the analytical mode is activated. It is further assumed that there is an interplay, a dance, of affective reasoning and analytical reasoning (Finucane et al., 2003). I derive the first conclusion that any judgement of nuclear risk is primarily an *affective judgement* based on experience. This judgement is influence by past information of the risk. The information is associated to feelings, mostly negative or positive feelings that have been tagged or mapped, or associated over time with the risk source. Information based on proportions or numerically classified outcome figures differ in the ability to be mapped due to different human strategies to process information. I derive the second conclusion that it is possible that in the unexpected case of an accident for the interplay of affect and reasoning to lead to an increase in the gap between laypeople and experts. On one hand, laypeople will perceive the information as a negative stimuli and will judge the risk as less beneficial and riskier, due to the inverse relationship of risk and benefit judgements of a risk. Therefore, I assume that risk perception on nuclear energy for laypeople should increase after an accident. On the other hand, where experts are concerned, I assume that in the case of an accident, if the number of fatalities is low, an expert's risk perception will not change, in fact it might even reduce it. The prototype expert, completely relying on the analytical mode of reasoning, will judge a risk on an event's probability and an event's consequences. Since an accident is likely to happen according to the laws of probability at any moment with the same assumed probability only the consequences will be evaluated. If the magnitude of an event is lower than expected, e.g. if less people die, an prototype expert's risk perception will not increase.[41] Experts' nuclear risk perception therefore, I conclude, will remain quite stable over time.

The theoretical implication of the affect heuristic furthermore sheds light on different mechanisms for decoding and translating information about risks. Experts' risk judgements depend on the accepted social factors that are rationally considered to be taken into consideration for an indicator of consequences, such as a cost/benefit utility judgement by the risk experts' community. Experts' information of reality is encoded in abstract symbols, like words and numbers, perceived through conscious appraisal. In contrast I assume, that prototype laypeople base their judgements on a categorical judgement, like good/bad or dangerous/not dangerous. The information about reality is rather encoded in images and narratives, perceived through vibes and feelings.[42]

I want further take into consideration the aspect of biases in human reasoning, as mentioned in research and used in scientific language. I claim it is a misleading term. I think that the nature of reality leads to the illusion that there are biases in human reasoning. The existence of a bias is, as far as I understand, an indicator for an observer's inner structure of ignorance, as introduced by Smithson (1989). I believe that ignorance structures in society, designed to eliminate uncertainty, create biases. On the contrary, ignorance structures that incorporate uncertainty do not create biases. The first one is a closed system of human reasoning, the later one an open system of reasoning. Both systems are necessary for societal functioning and the interplay of both systems bear the forces for peaceful social change. Changes based on both, analytical and experiential knowledge, are necessarily biased from either point of view. Bias in that sense is a representation of uncertainty. Knowledge in that sense is a term for the whole spectrum of information of conscious or unconscious, past and present, encoded reality. If there are no socially created biases, but only uncertainty in human reasoning, the act of listening becomes more important in order to create awareness, to understand and learn of other abilities and techniques for encoding reality. I assume that the aspect of mutual recognition of different and contradictory aspects of human reasoning will be a key element to create socially accepted governance structures that are able to govern risks in the future. I will discuss this point in more detail in Section 9 of risk governance.

[41] It might even be the case, that the additional information will lead to an improvement in nuclear safety standards imposed by regulation agencies. In that case it is possible that experts' nuclear risk perception will increase again, because benefits of technology (measured in terms of cost/benefit calculation, not in fatalities this time) will decrease, making nuclear a less attractive technology.

[42] These assumptions, I ask to consider the reader, are only ad-hoc reasoning based on my summary of previous research. Research in this field is only beginning to get a better understanding of the complex structure of human reasoning as Finucane and colleagues emphasis (Finucane et al., 2000a, 13).

4.2.8. Social amplification of a risk's sound

So far I have laid out a multifaceted concept of risk. Starting from a discussion on the ontological and epistemological interpretation of risk, then broadening and opening the scope to the more complex processes that shape individual's risk awareness, judgement, and evaluation. So far two major points remain still unanswered. First, why is there a gap between experts' and laypeople's judgements of risk. Secondly, why do some risks, like nuclear power or risk events, like a nuclear accident, seem to induce high levels of public concern with social and economic consequences while other risks do not seem to have the power to actually bring forth change in the social reality. The work done by Slovic (1987) (compare Section 4.2.3) explains in part the complex nature of risk perception, for example the influence of a risk's perceived catastrophic potential. He furthermore mentioned a hazardous event's potential effects that ripple across social boundaries, the drop of water in a teacup. The social amplification of risk framework (SARF) (compare e.g., Kasperson et al., 1988, 2003; Pidgeon et al., 2003), as I will explain in this chapter, has the aim to be a comprehensive concept of how risk is experienced in society (Renn et al., 1992, 138). Risk perception in this framework is understood as a broad concept of how uncertainty is processed in society and how the potential or actual consequences of an event or activity, are evaluated and perceived. Risk from that perspective is created by observing and communicating actual or hypothesized risk events like accidents or incidents (compare Luhmann, 1990). Risk is related to social knowledge and social decisions or reactions to existing danger. Danger in that sense is the possibility of future damage related to external events (Luhmann, 1990, 225). According to the underlying theoretical concept, risk events, if not detected and communicated, are more or less irrelevant for the existing social order (Kasperson et al., 2003, 15).

According to the framework, as consequences of communication processes, transformation processes are implemented and the results are changes in technologies, in social practices, such as land cultivation, in ideological structures and cultural identity patterns. The awareness of risk is not only the experience of a physical harm and the direct reactions to that harm, but a consequence of a process of interpretation of a hazard, involving different social actors and decision making processes. Risk in that sense is to some extend an objective property of an event and to some extend a social construct (Short, 1989). A concept neither squeezed into the narrow scope of technical determinism and neither dismissed into the arbitrary spheres of total relativism. The need for a broader framework to explain the complex structure of risk perception and social responses to hazardous events is obvious.

The social amplification of risk framework is an attempt to integrate different approaches in risk perception, as well as risk communication research able to combine existing studies from the psychometric studies of risk perception, cultural studies, media research, and from studies of organizational responses to risk (Kasperson et al., 2003, 13).[43] The motivation to design a new theoretical concept arose, as emphasized by the authors of the initial SARF-paper in 1988 (Kasperson et al., 1988, 178), from the need to explain why more or less minor risk events, from an experts' point of view based on technical risk assessment, can result in unexpected massive public reactions with socio-economic and political impacts. The puzzling reality on risk is that on the one hand there are the hazardous events like chemical, nuclear accidents, aviation accidents, terror attacks, or diseases that are able to create increases in public focus and concern, termed in the SARF terminology as risk *amplification*, while at the same time risks such as radon gas, smoking, or automobile accidents receive only a limited fraction on public attention from society, resulting in, what is termed in the SARF terminology, risk *attenuation*.

Known factors that shape individual's risk perceptions are familiarity with a hazard, voluntariness and the catastrophic dread potential of an adverse event (compare Slovic 1987). Also heuristics have been broad forward to explain how people intuitively process risk information (Tversky and Kahneman, 1973; Slovic et al., 2007). The shortcoming of these mostly psychological studies are that they ignore the complex nature of information processing and exclude different social and cultural context factors that might influence individual risk evaluation. I also mentioned sociological approaches that focus rather on the organizational capability of risk management and the underlying power structures, due to competing demands of various social groups that shape risk decision making processes (Perrow, 2006, 1999). This social amplification of risk framework incorporates given approaches and tries to explain how a risk event is perceived by individuals and might lead to unexpected higher-order social impacts, not related to the initial event.

The amplifying process (compare Renn et al., 1992) starts with a risk event. The event can be a sudden physical event, like a nuclear accident, or it could be an increased awareness of hazardous events, like the problem of nuclear waste storage, or in the non-nuclear scenario the discovery of e.g., the ozone hole. Individuals and social groups, in a next step, detect different characteristics of the event and decode or interpret them according to their given mental modes or societal perceptions. The perceived information is then transformed into messages and communicated between individuals or groups. In this sense, individuals and groups, act as amplification stations through communication processes and behavior (Renn et al., 1992, 140). Risk then is more than the experience of the physical harm or the perceived direct magnitude of consequences, as posed in traditional risk assessment, it can only be properly assessed when social interaction processes are considered that also shape the interpretation of the event or the existing risk information. It is possible that some events lead or – to keep the terminology of the teacup – ripple through society leading to secondary or tertiary consequences, affecting

[43] As Renn and colleagues (1992, 138) point out, the assumption of traditional risk analysis of risk as a concept of probability and magnitude of consequences, even thought formally correct, does not match the perceived reality in society leading to misunderstanding and sophisticated ignorance statements (Freudenburg, 1988). Referring to Douglas and Wildavsky (1983), the authors rather enhance social values and attitudes as well as cultural identity as influencing factor of how people perceive and react to risks.

unrelated technologies, markets or social institutions at distant places. Such higher order impacts are impacts for instance on markets through changed consumer behavior, stricter regulation, litigation, stigmatization of products, communities or facilities, or a loss of credibility and trust. Kasperson at al. (2003, 16) point out that the spread of an initial risk event transforming into a societal risk experience of higher order impact is an important part of the risk amplification framework, because the spread of impact might enforce, in the case of risk amplification, or might put constraints to, in the case of risk attenuation, political interventions of risk reduction: "The social structures and processes of risk experience, the resulting repercussions on individual and group perceptions, and the effects of these responses on community, society, and economy compose a general phenomenon that we term the *social amplification of risk*" (Kasperson et al., 1988, 179).

To illustrate the higher order effects that are conceptualized in the framework I want to show, the hypothesized effects (Kasperson et al., 1988, 182). According to the authors secondary or any higher order impacts as a consequence of a risk amplification or attenuation process through behavioral responses are effects such as:

- effects on affection, perception or images of a risk, like attitudes against technology, social apathy or stigmatization of a technology, environment or risk managers;
- effects on the physical environment of a risk, like impact on local sales, property values or economic activities;
- effects on political practices or social order, like a change in the political climate or culture and additional social demand and pressure on political institutions;
- effects on the physical nature of the risk itself, like additional social practices (feed back mechanisms) controlling the risk;
- effects on the direct reaction of a risk, like social disorder and protests, better regulation, change in training, increased liability, change in trust and acceptance of other technologies or social institutions that govern society.

Higher order impacts of risks as presented above are able to change the social structure unexpectedly and in various ways. A critique by Rip (1988) on the framework also mentions that the framework is designed rather to explain the intensification of a risk, based on fatal events, like the Three Mile Island accident and social reactions to that event, than the constant and distant changes of the social risk structure, unnoticed by the public or most social organizations. This critic also points out that the nature of the signal is the key element in the starting process of risk signal amplification or attenuation. It is thus important to understand how risk signals are socially interacted (Rip, 1988, 194).

In the social amplification and risk framework, the interaction, i.e. the amplification or attenuation of risks and its risk signals, happens through processes that transform and filter the receiving signals according to the given social rules and procedures. Information passes through social or individual amplification stations, increasing of decreasing the volume of the initial risk event. The communication process emphasizes certain aspects and can alter the symbols and images associated with the signals. Amplification stations are individuals, members of social groups, or members of institutions such as the mass media, scientific institutions, non governmental organizations, political institutions, or governmental agencies. The communication culture and the worldviews of each amplification station can influence the amplification process of risk events (Peters and Slovic, 1996; Vaughan, 1995).

According to the authors of the framework (see Kasperson et al., 1988, 2003; Renn et al., 1992), the framework is not a fully developed theory, rather a conceptual framework providing a guideline to describe and test risk problems. The term of amplification is taken from communication theory to underline the idea of the attenuation and intensification of signals during its transmitting process. Information is transmitted from an information source through various intermediate transmitter before received by an receiver. “An information source sends out a cluster of signals (which form a message) to a transmitter, or directly to the receiver. The signals are decoded by the transmitter or receiver so that the message can be understood. Each transmitter alters the original message by intensifying or attenuating some incoming signals, adding or deleting others, and sending a new cluster of signals on to the next transmitter or the final receiver where the next stage of decoding occurs” (Kasperson et al., 1988, 180) the authors explain.

The metaphor of amplification has been criticized by Rayner (1988, 202) for of not representing the complexity of the risk evaluation process. Rayner points out that the idea of a passive signal, created by a risk, perceived, transmitted, and received does not reflect the initial problem. If risks and its information are already part of a social process, the most interesting question is how the signals are selected, transmitted, and perceived in different ways. The technical metaphor of an amplification station might be, from some viewpoints, a jammed transmitter for the concept. My response to this critique is that the technical term of an amplification process, based on the idea of signals, is very useful to emphasize the active act of processing information. If a signal is the basic unite of a message, the key question for any risk assessment process is how signals are evaluated and judged. Socially learned techniques which create an awareness of signals are then a main point of interest, in my opinion. A better understanding of these techniques will also help to combine different viewpoints or at least create an awareness that there are many ways to react and interpret signals. The term signal enables the risk entrepreneur to observe the context that creates distinctions of higher-order observations (Luhmann, 1990, 224). In their reply to critique Kasperson and colleagues (2003, 37) similarly argue that the conceptualization of the amplification process, the process of transmitting information through social or individual stations, does include the meaning or is based on the idea that any knowledge of a risk is to some degree socially constructed.

Indeed, it is the context not only the content of decision making that is of interest for the researcher. Kasperson et al. (1988, 180) point towards the complexity of transmitting information in a social context. From their point of view, signals and their messages have only a meaning within an existing sociocultural context. Without guiding mechanisms, a receiver is not able to encode the meaning of a message. Sources and signals in that sense are not independent entities. A receiver perceives and links the signal to the source, or previous transmitters, and forms an opinion about the relationship. Each message can contain different meanings, with factual, inferential, value-related, and symbolic meaning (Kasperson et al., 1988, 180). A factual message delivers the facts about the source of a risk, such as ‘a nuclear power plant in Japan’ and the content of the risk, ‘emission of dangerous substances’. An inferential message provides information about possible consequences that can be drawn from the given situation, for instance ‘the emissions exceeded a certain level and are a health threat’. Cultural symbols are attached to a risk source and transmitted by both factual or inferential messages due to value implications associated with some social institutions. In the case of nuclear industry there can be symbolic connection, such as to protests at nuclear test sides or to a clean and cheap source of energy.

According to the concept of the social amplification of risk framework, signals are processes by individual and social amplification station through communication devices like media, written conversation, or direct conversations. Social amplification stations are according to Kasperson et al. (Kasperson et al., 1988, 181) institutions and people, such as:

- scientists or scientific institutions who provide and create knowledge, like the technical assessment, of a risk;
- public agencies;
- risk management institutions;
- non-governmental social activist organizations;
- personal networks and peer groups;
- opinion leader within social networks, social groups or social organizations.

Social amplification stations engage in the risk communication process in many ways: by using heuristics to process information, by attaching personal or institutional values to the information, by interpreting the perceived message within the personal network to validate the information. The validation or the feeling lead to behavioral intensions to either take actions or to tolerate the given risk situation, to finally take actions to tolerate, accept, ignore or to change the risk (Kasperson et al., 1988, 181).

It is furthermore assumed (see Kasperson et al., 1988) that individual or social amplification stations are able to change the intensity of a signal. The amplification of a signal is able to happen at any stage of the transmitting and receiving process, or even twice when the message is received and recoded. A transmitter structures the message before sending the message to a receiver. When receiving the message, the receiver encodes the message and evaluates the signals. Any transmitter is also a source of new information because the original message is firstly translated from the source into a new message before send to the receiver. The encoding and translation of a message follows institutional rules and different expected interests of the receiver or transmitter according to their role requirements. Social groups or social stations of amplification act according to their own rules beyond individual values or interpretation patterns; they act in accordance with their interests, and encode or transmit information with their own historically grown standards: the scientific community processes information with a different standard compared to a media editor board of a news magazine or a press agency of a political institution.[44] In this sense, it becomes obvious that risks are a social experience and any stage of processing information can be assumed to contribute to the perceived consequences of a risk: "Social amplification of risk denotes the phenomenon by which information processes, institutional structures, social-group behavior, and individual responses shape the social experience of risk, thereby contributing to risk consequences" (Kasperson et al., 1988, 181).

In my concept of a social risk entrepreneur the individual still is the focal point of interest.[45] Each individual, as single unit or part of a broader social group, firstly reacts with an individual decision to a risk signal. In this sense, a risk entrepreneur is at first a receiver of information. The individual also is a holder of given (a-priori) information. Four aspects shape risk information processing and signaling: 1) the intensity of the new information, 2) the given (a-priori) information, 3) the decoding and evaluation process of the new information, and 4) the process of combining or integrating both (a-posteriori) information. All four aspects are able to constantly change risk signals through social transmitting by either increasing or decreasing a signal's volume. The above described decoding depends on the compatibility or inconsistency with previous beliefs, stimuli or values and results either in ignorance, with the consequence of attenuation, or in attraction, resulting in intensification of the signal: "The decoding and evaluation process determines the receiver's selection of significant information. The components of the decoded message that are inconsistent with previous beliefs, or that contradict values to which the receiver feels attracted, are ignored or attenuated. If the message is attractive or consistent with previous beliefs, the signals are intensified" (Renn et al., 1992, 141).

Renn et al. also provide a detailed scheme of eight steps of how individuals process signals and draw inferences by encoding and translating information of risks (Renn et al., 1992, 142: Table 1 "Steps in individual perception of information"; own formatting):

[44] Tetlock's (2002) idea of different sets of functions and encoding strategies of risks, compare Section 4.2.6, can be applied to to the SARF concept.

[45] A focal point in the sense of the definition by the New Oxford American Dictionary: "the point at which rays or waves meet after reflection or refraction, or the point from which diverging rays or waves appear to proceed." (NOAD, 2005)

1. "**Passing through attention filters**: Selecting and further processing signals from the environment, other individuals, and the media".
2. "**Decoding of signals**: Deciphering the meaning of the signals (investigating factual content, sources of information, explicit or implicit inferences, value statements, overt and hidden intentions of information sources and transmitters, and cues to assign credibility of information and information source)".
3. "**Drawing inferences**: Arriving at conclusions about the allegedly revealed intentions of the source and the transmitter, employing intuitive heuristics (common sense reasoning) for generalizing the information received, and using symbolic cues for judging the seriousness of the information"
4. "**Comparing the decoded messages with other messages**: Analyzing the meaning of the message in the light of related messages from other sources or previous experience"
5. "**Evaluating messages**: Rating the importance, persuasiveness, and potential for personal involvement on the basis of the perceived accuracy of the message, the potential effect on one's personal life, the perceived consistency with existing beliefs (to avoid cognitive dissonance), reference group judgement (to avoid social alienation), and personal value commitments".
6. "**Forming specific beliefs**: Generating or changing beliefs about the subject of the message or to reassert previously held beliefs".
7. "**Rationalizing belief system**: Sorting and reinterpreting beliefs in order to minimize cognitive dissonance".
8. "**Forming a propensity to take corresponding actions**: Generating intentions for future actions that are in accordance with the belief system".

(Source: Renn et al., 1992, 142)

The information processing draws the attention to an important aspect: risk is more than a rational or technical term; risk is more than a feeling or experience; risk is more than the existence of a risk source; risk is also a social information you can listen to; risk is a sound! Risk is the sound of uncertainty or in the strict sense the sound of ignorance. Whereas in the previous concepts risk was perceived as a constant entity, in the social amplification of risk framework risk is a non constant entity; each signal carries the capacity to change in volume at any time. The non constant nature of risk holds for both the objectivist perception of a physical risk and the constructivist perception of socially created risks. If risk has access to uncertainty the interplay of physical processes, analytical and experiential reasoning as well as communicative interaction is able to constantly change the existing information, due to the information contained in uncertainty. If the described interplay exceeds socially accepted boundaries risk becomes visible and might change its volume, making the new information perceivable – a new sound emerges – and changes the ignorance structure in society. I might go too far, but risk in this sense is an own organism, or an indicator of a more integrated social system.

A risk entrepreneur who is constantly sensing the existing uncertainty structure might be able to listen to the change in the ignorance structure. She or he is not only able to understand and speak the different mental modes and the encoding schemes of information, as described for example by Epstein and colleagues (1992), he or she is also actively listening to the signals. The entrepreneur is part of the risk structure and also outside of the existing communication processes, because an entrepreneur is a social amplification station and in this role constantly changing the ignorance structure and the existing risk signals. In this sense, it is impossible to be the independent higher-order observer of the world in the sense of Luhmann (1990), since signals are transmitted through the whole risk organism and it might be beyond human ability to exclude oneself from this process. The art of change for a risk entrepreneur could then to be an amplification station that receives, encodes, and translates all available signals in order to form a message and to send the signals that best represents the existing information of the present ignorance system. The hypothesized abilities of listening to the sound of risk go beyond – as far as I know – scientifically accepted evidence and empirical testing. The sound of risk might also only be a metaphor that helps to describe the integrating power of risk for individual, social, and other forms of life on earth. Listening to the sound of risk enables humans to listen to each other, not by silencing voices but by enabling voices to speak and to be integrated in the existing dialogues. Risk in my opinion, therefore, is not only changed by technical solutions, but by communicative processes. Balancing the sound of risk is an art to be discussed at the end of my dissertation.

In line with the above described scenario of spaces of ignorance, the authors of the social amplification of risk framework are interested how risk or the perception of risk is processed in the information system: "The interaction between risk events and social processes makes clear that, as used in this framework, risk has meaning only to the extent that it treats how people think about the world and its relationships. Thus there is no such thing as "true" (absolute) and "distorted" (socially determined) risk. Rather the information system and characteristics of public response that compose social amplification are essential elements in determining the nature and magnitude of risk" (Kasperson et al., 1988, 181). Empirical research using the approach has tried to test influencing factors and the causal structure of the interaction process.

On the individual level a study by Trumbo (1996) evaluated the relationship of the dread/knowledge dimensions, proposed by the psychometric work of Slovic and colleagues (e.g., Slovic et al., 1981) and the classification of individuals as risk amplifiers or attenuators. He found that amplifying a risk correlates with the perceived individual risk whereas attenuating a risk correlates with the satisfaction of institutional responses.

Empirical findings of a 128-hazard-event study (Renn et al., 1992; Kasperson et al., 1992) reveal two major aspects for risk perception research. First, it seems that social responses to hazards are based on rationality and rational reasoning, in contrast to the widespread opinion that people's judgements are biased. Second, when comparing the magnitude of casualties and the extend of exposure to a risk, it turned out that exposure to a risk is more likely to shape individual risk perception. It seems that exposure to a risk is a more influential factor than previously recognized since it also correlates high with higher-order impacts like media coverage and public responses. Pointing out to the interplay of magnitude 'of' a risk and exposure 'to' a risk the authors conclude that "these findings are particularly interesting because expert judgements on risks usually rely on estimates of expected fatalities rather than on exposure. These results show that individuals took exposure as their reference point, whereas the media and some societal groups seemed to take into account both of these characteristics of hazard (though they also placed more emphasis on exposure). However, the fairly high correlations between the number of casualties and the magnitude of social impacts suggest that human harm is also a major driver of societal impacts" (Renn et al., 1992, 151).

The media reflects both magnitude of and exposure to risks. This means that exposure as the main driver of risk perception is able to be transmitted through society by media and amplified by social interaction in personal networks. The observed process of amplified risk signals through individual and social processes is able to produce higher order social consequences, as assumed by the framework (Renn et al., 1992, 154). The observed gap between risk experts and laypeople in the seriousness of a risk might also, at least to some part, be explained by the observed different weighting of magnitude and exposure. A toxic cloud, the authors offer as example (Renn et al., 1992, 154-156), traveling above a large area, with no casualties might be perceived as more dangerous compared to a toxic cloud in a building that leads to several people injured or killed. The causal analysis of the interplay of different factors also reveals that magnitude of physical consequences of an event is influencing societal impacts only indirectly (Renn et al., 1992, 156). The results of the 128-hazard-study reveal an potentially underlying structure of higher-order impacts. The results, as the authors critically remark, cannot prove the causal mechanisms completely because higher-order impacts such as magnitude of and exposure to a risk have been estimated indirectly through experts' judgements. These indicators were reliable measures, but their validity could not be tested.

Further research, analyzing the role of mass media (by analyzing newspapers) concludes that the amount of coverage of a risk event is not resulting in a massive amplification of risk perception (Freudenburg et al., 1996, 40). The role of media is important in shaping overall awareness of a risk, and also creating the space to discuss risks (Vaughan and Seifert, 1992). Media's role as a social amplification station is also limited because of a tight interrelation of media and other contextual factors, historical facts, and social group interests. I conclude, after discussing the above mentioned literature, that in the same line as the public is not the chaotic and irrational receiver and sender of risk information, research also indicated that the volume of media coverage is not the main loudspeaker of social amplification processes.

Research on organizational management of risk and processing of risk information also reveals that the volume of signals can be amplified and attenuated due to many factors that are influenced by the structure and the communication culture of an organization (Freudenburg, 1992, 1993; Short, 1992; Perrow, 1999; Turner and Pidgeon, 1997; Turner, 1978). A bureaucratic attenuation of information flow or the self-interest of divisions, economic constraints or interests, management's vanity and messy rule of thumb decisions, as well as complex historically grown animosities within organization are influencing inter- and intra-organizational relationship. These processes can result in an underestimation of risks, and in an ignorance and accumulation of risk signals until, eventually, a risk event occurs. The unprepared organizational reaction to an event is then a signal that is perceived by the affected or not-affected population and shapes individual's risk perception and trust in higher-order institutions. If the risk management of a hazard is brought into question because of public's concern about the safety or controllability of a risk, stigmatization can happen. As the word stigma implies, an individual or place is marked as disgraced because it lost its reputation and respect and is considered as a risk for society.

Stigmatized risks are likely to have higher-order impacts and to ripple across original boundaries. Studies of stigmatized technologies, like nuclear power (Flynn et al., 1998) or nuclear waste facilities (Slovic et al., 1991), reveal that a nuclear technology, once perceived as the promise of modernity and endless welfare, can be stigmatized irreversibly into an object of dangerous threat and an example of distrust in management and regulation agencies across social communities.

Stigmas emerge, as Gregory et al. (Gregory et al., 1995) conclude, if a known or unknown social standard is violated by a social actor. For instance an oil spill, such as in 2010 in the Gulf of Mexico the Deepwater Horizon oil spill, is polluting (perceived innocent) beaches and endangering the (as innocent tagged) wild life in the area. Hazards, characterized as dangerous or involuntarily exposed, as well as impacts that are perceived as inequitably distributed are more likely to be stigmatized in an case of a risk event as risks with other characterizations. It is also the case, such as in the case of nuclear waste repositories, that geographical areas are stigmatized because of the higher risks the area entails. Stigmatization can also be perceived as an indicator of inequitable distributed risks, Kasperson and colleagues point out (Kasperson et al., 2003). The authors explain that what is marked as stigma is often related to uncertainty, ignorance, and non-knowledge. Even though stigmatization happens in society, the complex nature of stigma, i.e. the mechanisms to understand stigma and the direct effects of stigmatization, can only be well understood by controlling the social, cultural, and economic structure of a community or stigmatized technology (Gregory and Satterfield, 2002). Stigma, can be concludes, is one amplification mechanism explaining how people respond to information about a risk (Kasperson et al., 1988, 185-186).

Kasperson and colleagues (2003, 31) point out that social trust can be considered as a social amplification mechanism for higher-order impacts. Trust, like trust in people, technologies, or institutions seems to be an important factor that determines how people perceive, transform, and respond to new information (Cvetkovich et al., 2002). Trust can be considered in the framework as a higher-order impact, because of its asymmetric nature (Slovic, 1993, 2000b). As will be explained in more detail below (see Section 5.2.3), trust is created over time and based on many trust building processes. Throughout the whole trust building process, social trust keeps its fragile nature, i.e. it can be easily destroyed and it is difficult to recover trust after a trust destroying incident. According to the asymmetry principle, negative events tend to be more visible and, hence, have a higher impact to destroy trust than have positive events. In contrast to the rather fuzzy, ambiguous, or elusive nature of positive events (Kasperson et al., 2003, 31) negative events such as accidents, a lying and misleading management, or other forms of apparent lack of responsibility, are well-defined and take a specific form, that can be easily perceived, communicated, judged, and classified (analytically or emotionally) as good or bad. Hence, in a risk evaluation process, a trust destroying event gets greater weight compared to the number of invisible or ambiguously defined good (non-negative) events (Cvetkovich et al., 2002).

Social scientists analyze trust as part of the political culture and as part of a society's social capital (Inglehart, 1988, 1990; Coleman, 1990; Putnam, 1993, 1995). For a community or social entity trust creates expectability through mutual confidence. If trust is shared within the community in a more specific context trust, is transformed into credibility of each social actor. Social trust can be defined as "a person's expectation that other persons and institutions in a social relationship can be relied upon to act in ways that are competent, predictable, and caring" (Kasperson et al., 1992, 169). Credibility is aggregated trustworthiness and, in contrast to trust, can be defined as "the generalized impression of an enduring and continuous experience of the trustworthiness of an organization" as Renn draws the line between credibility and trust (Renn, 2008, 223). Trust is a social construct created over time trough a manifold system of mutual recognition and assurance and social communicative and behavioral processes.

Ortwin Renn assigns seven components to characterize trust (Renn, 2008, 223: Table 7.1, (own formatting); see also Renn and Levine, 1991):

1. "**Perceived competence:** The degree of technical expertise in meeting an institutional mandate"
2. "**Objectivity**: The lack of bias in information and performance as perceived by others"
3. "**Fairness**: Acknowledgement and adequate representation of all relevant viewpoints"
4. "**Consistency**: Predictability of arguments and behavior based on past experience and previous communication efforts"
5. "**Sincerity**: Honesty and openness"
6. "**Faith**: Perception of goodwill in performance and communication"
7. "**Empathy**: Degree of understanding and solidarity with potential risk victims"

(Source: Renn, 2008, 223: Table 7.1.)

Trust itself is not always attributed to the risk source or the risk signals as such, but rather to underlying basic values that evaluate the behavior and the risk communication processes of risk administrators (Siegrist and Cvetkovich, 2000; Siegrist et al., 2000). In order to avoiding higher-order ripple effects, the risk communication process gains importance and weight in the risk management procedure. A successful strategy for avoiding societal conflicts on a risk source can be to address and include all basic values of the affected community into the risk assessment process (Edwards and von Winterfeldt, 1987; Arvai et al., 2001; Rayner and Cantor, 1987). In creating a higher-order trust structure, the process of finding a solution that people in agreement with can be efficient both in terms of exchanged information and avoiding conflicts on the individual and on any higher-order level.

The concept of the social amplification of risk shows that the basic evaluation of risks and its risk signals depends on the existing social structure of risk perception, the trust structure, and the culture of how the risks have been implemented into society. The risk communication process, as the major factor in creating trust, acceptance, and credibility towards a risk source and its management, is one of the key elements of effective and sustainable risk governance. As described above, trust is based on successful management of a risk source and effective risk communication (Kasperson et al., 2003, 45). Studies clearly indicate (compare e.g., Kasperson et al., 1992; Flynn et al., 1993; Jenkins-Smith, 1991) that distrust affects risk perception positively (increase in risk perception), changes public reactions to risk signals positively (increase of risk signal volume) and changes acceptance of a risk negatively (decrease of acceptance). The lack of trust also leads to higher political activism or, if that is not possible, to social apathy.

My summary of the social amplification of risk framework is framed so as to show the complex interplay of psychological, social, political, and economic factors that constantly shape and change a society's risk arena. The framework is not a fully developed theory and it is important to mention, that only empirical evidence will prove the applicability of the framework. For my research on risk perception, it is a useful concept that helps to explain empirically observable anomalies in risk perception research. The technical view on risk is not enough to understand the nature of risk perception and the underlying factors that influence risk communication processes. I hypothesize that 'how' not 'what' is the key question of risk management processes in the future: How are risks created? How are risks perceived? How are risks communicated? How are risks affecting communities? How is the sound of risk? The questions for the 'what' remain important: What is a risk? What is risk perception? What is effective risk communication?

The 'how' is describing an process with constantly changing states of the world: how it is, is perceived, felt, experiences or analyzed. The 'what' represents for me the scientific ideal of explaining what is and the ideal of moving closer towards the true knowledge – maybe it is an impermanent state of knowledge that is constantly changed and influenced by imperfect knowledge. The framework helps to remind that even the best explained 'what' is still an empirical question and will be proved by evidence and not by assumptions – Popper's (1959) black swan is looming everywhere. Maybe for the field of risk research, future research questions are not the disturbing sounds of risk and how to control them, but rather how to incorporate the sound of risk in a community's existing trust structure. Jasanoff provides some thoughtful insights related to my thoughts (Jasanoff, 1993, 2006). How does the old and endlessly wise sound of risk help humanity to become part of a growing global community? Or more specifically for my research: How does the sound of nuclear risk help to form a global risk governance community able to create credibility and solution to deal with the (negative or non-negative) risk of nuclear power for future generations?

In that sense I will continue in my dissertation to evaluate empirical results on nuclear risk perception research in a cross-cultural comparison. I will narrow my focus, leaving the broad and wide concept of the social amplification of risk framework, bowing in honor to the basic idea and the beauty of the efforts that came together to create such inspiring work. It might not be the final Arc de Triomphe or the Trafalgar Square of risk perception research. The framework nevertheless is a square of risk research bringing together different scientific approaches. The authors of the framework conclude: "a particular policy strength of the framework is its capacity to mesh emerging findings from different avenues of risk research, to bring various insights and analytic leverage into conjunction, and (particularly) to analyze connections, interrelations, and interactions within particular social and cultural contexts" (Kasperson et al., 2003). On that square there are different monologues and dialogues simultaneously happening (compare for an overview Figure 2 on page 8). I will focus on the space that is defined by the scientific dialogues on nuclear risk perception.

5. Contextual and individual factors shaping risk perception

In this section I will present theoretical approaches to explain observable and theoretically assumed differences in risk perception in the population, and provide existing empirical evidence to test theoretical claims. For my empirical research on nuclear risk perception, it is important to take a wide range of possible influential factors into consideration, before selecting the factors I can test given the existing data. Investigating the relationship of socio-demographic factors and risk perceptions helps to understand the complex nature of how risk perception is embedded in the public and in diversified social life (Vaughan and Nordenstam, 1991; Cvetkovich and Earle, 1985). To what degree conceptual assumptions and hypothesized relationships can be generalized across all groups of society, remains the perennial question in my research.

5.1. Introduction: what matters?

As mentioned and hypothesized upon in the concluding words upon the social amplification of risk framework, the evaluation of risks depends upon, aside from psychologic factors, individual factors and the existing social structure, cultural foundation, symbolic communication practices, and the institutional trust structure that exist in society. It is therefore not sufficient to consider risk judgements procedures as an independent mechanism that is solely based on technical, psychological, or intuitive evaluation patterns by single individual entities. For instance, the psychologic research does not address the question how historical or social and cultural influences shape individual opinions and judgement patterns of evaluating uncertain outcomes and qualitative risk characteristics

(Renn, 2008, 119). Anthropologist and sociologists have tried to define cultural factors that shape, mediated through cultural values, encompassing worldviews, that as such are influencing risk perception patterns.

According to the proponents of a cultural approach, social norms, values, and historically learned practices that are deeply rooted in society form social structures or social entities that react in a specific way to risk or express a certain kind of habitual risk behavior within their group (Beck, 1992; Thompson, 1980; Thompson et al., 1990; Sjöberg, 2006). Thompson for instance hypothesizes that different social patterns forming risk perception combine individual and context mechanisms of reasoning. Since there exist multiple patterns in society, more than one perception is possible. Depending on the observer's viewpoint these patterns are cultural biases of individuals risk perception: "Since risk is very much a moral question (and never more so than when it is being asserted that it is not) and since, as the history of risk assessment clearly demonstrates, widely divergent convictions as to what the risks 'out there' are can often coexist within the same society, this hypothesis should also provide us with a theory capable of handling these cultural biases both as to how risks are perceived and as to how they are evaluated" (Thompson, 1980, 6).

Sjöberg's approach is to address different view points on specific risks in society that have a deeper meaning and deeper roots than the easily identified gap between laypeople and experts. Pointing for instance to the "silent majority" (Sjöberg, 2006, 683), he addresses a group of people who tend to neglect risks and even create stable social mechanisms, like attitudes, to not accepting risks.

Given a social entity with different views on risk, the naive theoretical question that arises is: how is society balancing different risk attitudes?; or more specifically: how are different risk attitudes balances in a society with different cultural attitudes towards risks and socially created control structures to punish or reward each position? (Thompson, 1980, 4). The underlying assumption behind the question is that there are empirically observable differences within a society that can be explained by theories that address cultural, value or macro-context based explanations. These theories should also provide a reliable and valid classification framework. A question that further arises is: how are socio-demographic factors, such as gender, age, or social status able to explain differences in individual risk perception? To answer these questions, in this section I first discuss theories and frameworks that addresses the question of cultural factors; second, I analyze the influence of sociodemographic variables on individual risk perception; finally, I evaluate empirical research on cross-national differences in risk perception to develop a more global perspective on risk perception, focussing on nuclear risk perception.

5.2. Values, worldviews and institutional trust

5.2.1. Values

Values, as understood in social science, are constructed mental principles that provide guidance for individuals to judge or evaluate objects or situation as good or bad, desirable or unfavorable, as well as true or false to react in a specific behavior (Frankena, 2006, 638). What is valued as good or bad in a culture finds its expression through beliefs, moral principles, and social norms. Societies have created mechanisms to reward and sanction members who conform to or deviant from existing values. Hence, values do not change rapidly or unexpectedly and influence a member's individual identity, depending on the degree how someone accepts the existing values.

Public risk evaluation is influenced by value based judgements on risk qualities, like the equity in the distribution of risks, voluntary or involuntary exposure to a risk, or the perceived control over uncertain outcomes (Slovic, 1993, 675). Risk, from a social science point of view, expressed by Slovic (2000b, 392-393), is a deeply value-laden concept. A concept that has been invented by humans to understand a dangerous and uncertain world, and to cope with the consequences of that uncertainty. This subjective interpretation of risks, does not see risks as 'real' or 'objective' or independent of humans perception 'out there.' Dangers do exists, their interpretation is subjective and depends to a varying degree on cultural values.[46]

Technical or 'objective' risk assessment can be assumed to be based on rational values emphasizing efficiency and expertise. These values are formed by scientists and professionals in the risk assessment community. More democratic values emphasize subjectivity, experience, and historical and cultural understanding as foundation for risk evaluation processes. Fiorino (1989) states that the observed gap between experts and laypeople in their risk evaluation is the widest when rational risk judgements confronts laypeople's democratic and social values[47]. Fiorino concludes that these differences exist because they are "expressions of democratic values, and that these values affect lay reactions to risk problems" (Fiorino, 1989, 294). In this sense Ronald Inglehart (e.g., Inglehart, 1988, 1990, 1997) assumes a change in economically developed societies from materialistic values towards post-materialistic values. He describes a shift in a society's value structure from values that emphasize the security and the economical survival of a community towards the participatory opportunities and a community's individual as well as environmental health and wellbeing. From Inglehart's point of view, differences in

[46] Even technical risk assessment, like the probabilistic assessment of a nuclear accident, as Slovic (2000b, 393) points out, is based on (aggregated) subjective judgements and assumptions about the underlying theoretical models (e.g. the probabilistic theory) and conventions what information (e.g. the concept of fatalities) to chose.

[47] Social values Fiorino (1989) mentions are: social stability and cohesion, wisdom of past errors in the community, social distribution of risks and benefits, acceptance of management, ability for political participation, confidence and trust in agencies

risk perception can emerge due to different levels of materialistic and post-materialistic values among a community's members.

For modern societies, it can be assumed that different values and value cluster exist at the same time and that they find their expression in peoples assumptions and value judgements about risks. People who emphasize economic values might see technological development as a favorable mean to create and keep prosperity, while more environmental oriented people tend to disregard technological development and perceive it as a threat to one's own or the earth's health (Renn, 2008, 119).

Summarizing his insights on the state of value research, Renn (2008, 120: Table 4.6) defines four value cluster: traditional values, work ethics, hedonistic values, and post-materialistic values. Each cluster is defined by certain values (characteristics), that provide a certain function to society:

1. "Traditional values (examples: patriotism, ethic identity, social status, family stability) have the function of a group and cultural identity."
2. "Work ethics (examples: diligence, punctuality, efficiency, discipline, deferred gratification) have the function of functionality and efficiency."
3. "Hedonistic values (examples: consumption, enjoyment, fun, immediate gratification) have the function of incentive and motivation."
4. "Post-materialistic values (examples: harmony, social responsibility, environmental quality, decentralization, quality of life) have the function of moral legitimation and cultural commitment."

(Source: Renn, 2008, 120: Table 4.6)

In his evaluation of value research Renn (2008, 120) finds no evidence for a shift towards more post-materialistic values, event though they are expressed more prominent when people are asked for value preferences. Empirical research indicates that hedonistic and materialistic values tend to be ranked higher by individuals who rate technological risks and risks from economic activities lower. People who express preferences for environmental quality, social harmony, and democratic values tend to show higher risk perceptions for technological risks and economic activities (Boholm, 1998; Rohrmann, 1994; Edwards and von Winterfeldt, 1987). Furthermore, research indicates evidence that individuals open to technical change, career oriented in their work ethic, and liberal in their political view worry technological risks less then people who dedicated themselves to a more alternative and critical lifestyle (Renn, 2008, 121).

The statistical explanatory power of values in most empirical analysis is quite low and lower compared to the explanatory power of psychometric factors (Zwick and Renn, 2002; Sjöberg, 2000). It is therefore assumed that values influence individual risk perception rather indirectly, providing the individual decisions making process with selection filters and emotional or rational weighting mechanisms, especially in conflicting situations.

5.2.2. Cultural prototypes

It seems that, from the cultural theorists' point of view, risks are subjective interpretations of what a social context defines as risks. This implies that over time there should be a clear distinction between different social contexts, with shared values, worldviews, and social practices to exchange these views and, hence, different types or characters of risk perception. Thompson states when outlining his idea of a Cultural Theory: "The result of all this is that individuals in different social context will tend to home in onto distinctive strategies that will enable them to act so as to steer some optimal personal course through all these socially-imposed rewards and penalties" (Thompson, 1980, 5). He continues by reasoning that the mutual manipulation of individuals leads to a clear separation of different risk cosmologies, cultural clusters or cultural prototypes. In his approach to define a "anthropological theory of perception" (Thompson, 1980, 6), Thompson emphasizes that societies have a mechanism to create value based cluster that help people to distinct between different alternatives of perception in the way that the external world will be perceived through that cultural lens. Risk, in this sense, is a moral question. The integration of moral judgements into technical risk assessments or into the psychometric research might close the puzzling gap between experts' and laypeople's risk perception as Mary Douglas and Aaron Wildavsky outline in their book 'Risk and Culture': "[...] the key terms in the debate over technology are risk and acceptability. In calculating the probability of danger from technology, one concentrates on the risk that is physically "out there," in man's intervention in the natural world. In determining what is acceptable, one concentrates on the uncertainty that is "in here," within a person's mind. Going from "out there" to "in here" requires a connection between the dangers of technology and people's perception of those risks. Neither the one approach (that the perils of technology are objectively self-evident) nor the other (that all perceptions are subjective) can connect the two. Only a cultural approach can integrate moral judgements about how to live with empirical judgements about what the world is like" (Douglas and Wildavsky, 1983, 9-10). The authors state that people ignore most of the dangers that are surrounding them, what leads to a bias of selected aspects.

Ignorance is identified as the distinctive factor why people worry about some risks and chose a way of life that is adopting to that risks. Therefore, each form of social life is resulting in a specific "risk portfolio" (Douglas and Wildavsky, 1983, 8). These portfolios also implicate that within certain groups with given values some states of the world are feared and some are not feared: "common values lead to common fears" (Douglas and Wildavsky, 1983, 8). As already stated by Jasanoff (2006), Douglas and Wildavsky claim that the distinction between 'perceived' and 'real' risks does not exist until the danger had happened and the actual social behavior can be evaluated. What is defined a-priori as risk, i.e. before the danger happens, is based on social selection mechanisms, emphasizing some and ignoring others: "The cultural bias is integrated to social organization" (Douglas and Wildavsky, 1983, 8). The "cultural selection of danger" (Douglas and Wildavsky, 1983, 15) hence is an intuitive mechanism of social organization because individuals are not able to hold all possible views within themselves and are forced to choose and select between different biases. At the same time, by choosing or adapting to their social institutions they also choose their risk portfolio and their cultural bias. Each social form of organization has its own bias that enables them to find solutions for different kinds of danger. According to the Cultural Theory there is no such organization that can claim to be objective or unbiased; if so, only within their given worldviews and the dangers they face.

The cultural subgroups or cultural prototypes define what they perceive as risk. According to Thompson (1980, 2) society differs in two dimensions and various subgroups define themselves within this dimensions. The first dimension represents the density of group cohesiveness or the degree of identification with a group (the *group* dimension). In its extremes this dimension ranges from a society of 'individualized' entities (i.e. an infinite number of groups) and a society of 'collectivized' entity (i.e. one group). The second dimension represents hierarchy or to what extend the subject is accepting the given structures of a social system. That dimension shows to what extend the individual is involved into its organizational procedures, hierarchies and rules (the *grid* dimension). The *grid* dimension ranges from an 'egalitarian' society to a 'hierarchical' society.

In literature four or sometimes five types of cultural prototypes are defined: entrepreneurs, egalitarians, bureaucrats and stratified individuals (Douglas and Wildavsky, 1983; Rayner, 1990, 1992; Dake, 1992, 1991; Grendstad, 2000; Grendstad and Selle, 2000; Thompson et al., 1990). Thompson (1980, 3) defines also a fifth prototype, the hermit. In Figure 9 the different cultural prototypes are displayed and will be explained in more detail (compare Renn, 2008, 121–122, 122: Figure 4.1).

1) The 'entrepreneur' is characterized by a low degree of hierarchy and a low degree of group cohesion. The prototype's perception of risk is focusing on both short and long term risks with a tendency to favor short term risks. Risk are perceived as an opportunity and a chance to complete tasks and to reach individual goals. Risks for personal rewards are approves and risks for the benefit of all are less popular. Organizations or groups representing the entrepreneurial prototype do not perceive equity issues as a problem and want governmental regulation to refrain from regulation and to support competitive markets. This pragmatic view is legitimized by the maxim: "If I don't do it somebody else will do it" (Thompson, 1980, 6).

2) The 'egalitarian' prototype is characterized by a low degree of hierarchy and a high degree of group cohesion. The egalitarian prototype sometimes is also called the 'sectist' (Thompson, 1980, 3). Both long and short term risks are perceived, focusing on long term risks to guarantee the survival of the group. Risks for personal gains are penalized within that group whereas risk, taken by a member as a duty for the totality are symbolically rewarded. The principle is to avoid risks unless they are a threat to the whole entity or public good. Egalitarian groups developed a strong sense for solidarity and equity and are less interested in competition and individual freedom. Concerned about the long-term stability of the group, egalitarians developed mechanisms to abandon activities or risk taken social behaviors even though they might be perceived as opportunity, following

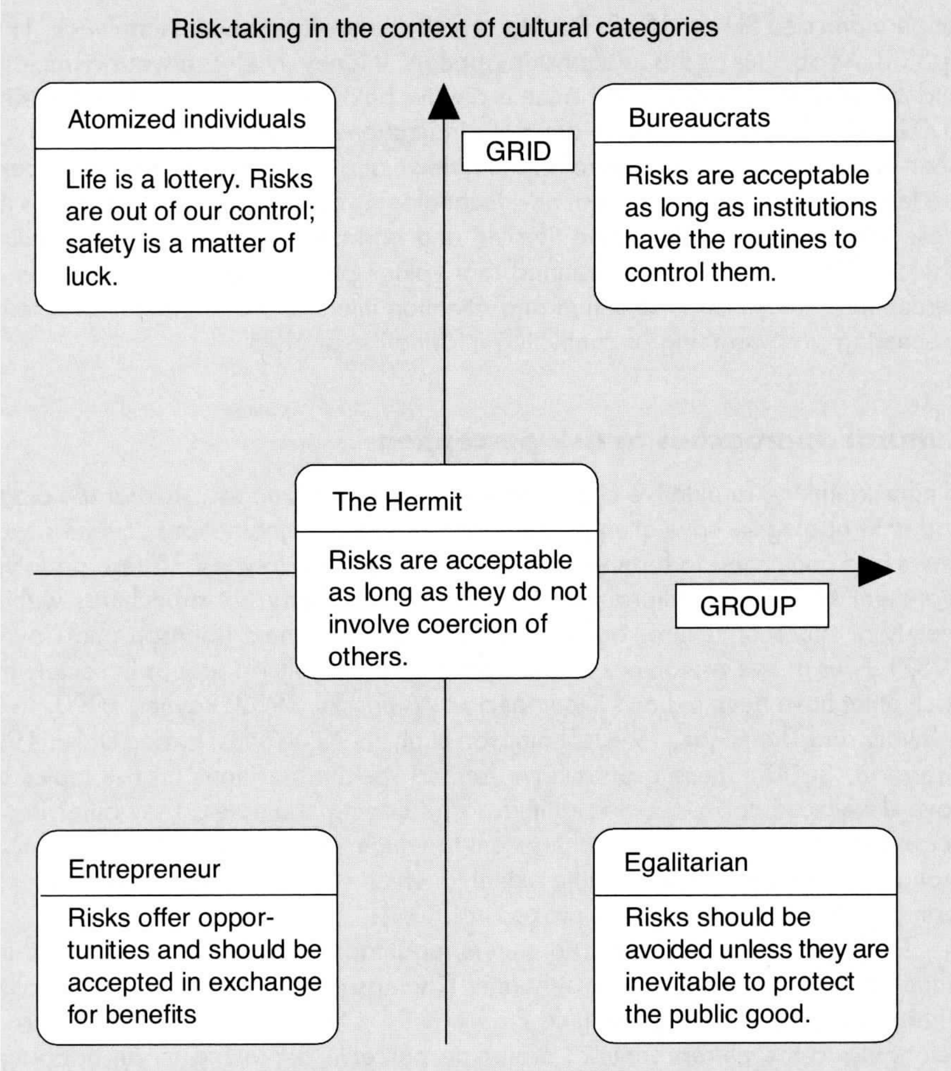


Figure 4.1 *Patterns of value clusters in the context of cultural theory of risk*

(Source: Renn, 2008, 122: Fig. 4.1)

Figure 9: Five types of cultural prototypes.

the collectivist's or egalitarian's survival strategy "small is beautiful" (Thompson, 1980, 6).

3) The 'bureaucrat' is characterized by a high degree of cohesion and a high degree of hierarchy. Long and short term risks are perceived as controllable. Rules and procedures, performed by capable management institutions will guarantee that risks can be handled safely. Bureaucrats rely on strategies and perceive a risk problem as solved when the best strategy is implemented through social organizations in society. Hence, risks are acceptable as long as organizations and institutions developed routines to control them. The collectivistic manipulation or control happens through ritualism. Bureau-

cratic groups or social entities rewards members who take risks for the totality and penalize risk taking behavior for personal gains. All risks can be controlled through social group mechanisms: there is “a place for everything” (Thompson, 1980, 6).

4) The group of ‘stratified individuals’ or ‘atomized individuals’ is characterized by a low degree of group cohesiveness and a high degree of hierarchy. People of that group believe in hierarchy but do not identify themselves with the existing hierarchies. Life is perceived as a lottery and the world a world of constant risks and changes. Since they do not accept the hierarchy, stratified individuals trust only themselves, are willing to take risks and also the rewards, since risks are a fact of life. They reject risks taken by the group and, hence, imposed on them. This prototype’s inherent confusion and perception of randomness hinders the individual to combine cause and consequences of risk situations; at the same time, as an individual survivor strategy, it enables the individual to belief, like a millenarianist, in a imminent better state of the world – a world without any risks.

5) The ‘hermit’ or ‘autonomous individual’, as fifth category, is placed in the center of the grid-group space. They are characterized low in hierarchy and low in group cohesiveness. Individuals of that group perceive short term risks and accept risks as an opportunity, if they do not get to involved in any hierarchy or group dynamics. These self-centered persons, are not going against someone or avoid to put pressure on someone if taking a risk – in contrast to the ‘entrepreneur’ they do not try to externalize the consequences of the risks they choose to take. Hermits are able to believe in hierarchy if they accept the hierarchy as a structure within a broader context of superior performance and knowledge. The short-term optimistic attitude towards risks (i.e. perceiving risks a-priori as an opportunity) on the one hand and their willingness to also accept institutional solutions or regulations on the other, enables autonomous individuals to mediate between different cultural groups in conflict situations.

Wildavsky and Dake (1990) and also Ripple (2002) developed measures to operationalize individual adherence to four cultural groups: hierarchical bureaucrats, egalitarians, individualistic entrepreneurs, and fatalistic atomized individuals (see also Oltedal et al., 2004, 22-24). Hierarchical group adherence was measured by asking questions about patriotism, law and order (e.g., “One of the problems with people is that they challenge authority too often” (Oltedal et al., 2004, 22)), ethical standards, and the lack of discipline among young people (e.g., “I think there should be more discipline in the youth of today” (Oltedal et al., 2004, 22)). Individuals or entrepreneurial worldviews were measured by questions upon support for continuous economic growth to improve quality of life, private profits, incentive oriented systems for those who work more and take more risks (e.g., “In a fair system people with more ability should earn more” (Oltedal et al., 2004, 22)), and weak governmental control (e.g., “A free society can only exist by giving companies the opportunity to prosper” (Oltedal et al., 2004, 22)). Egalitarian worldviews were operationalized in empirical studies on Cultural Theory by measuring attitudes towards social equality, trying to diminish distinctions in the system such as wealth, gender, race, or authority (e.g., “I would support a tax change that made people with large incomes pay more"; "The world could be a more peaceful place if it's wealth were divided more equally among nations"; "Racial discrimination is a very serious problem in our society" (Oltedal et al., 2004, 23)). The atomized individual's or fatalist's views were measured by asking questions on the unpredictability about life (e.g., "The future is too uncertain for a person to make serious plans" (Oltedal et al., 2004, 23)), distrust on social systems (e.g., "A person is better off if he or she doesn't trust anyone" (Oltedal et al., 2004, 23)), and the distrust of individual action (e.g., "Even if you work hard you never know if that will help you do better"; "It seems to me that, whoever you vote for, things go on pretty myth the same" (Oltedal et al., 2004, 23)).

Empirical studies by Dake (1991) and Wildavsky and Dake (1990), testing Cultural Theory's predictions, prove the expected relationships between worldviews and risk perception. People expressing a more egalitarian biased worldview perceived technological risks as high and ranked their benefits low. Risks that also rank high as dreadful and unknown in the psychometric approach (e.g., Slovic, 1987) such as 'the threat of a nuclear war' or the 'risks from nuclear energy' correlated high with the egalitarian view. People with a hierarchical or bureaucratic bias tended to rank risks higher that were challenging the given order, like the 'respect of authorities'. Entrepreneurs expressed their cultural bias by expressing higher concerns about the stability of economy and the freedom of choice, such as the 'stability of the investment climate' (Dake, 1992, 30).

Dake (1991, 78) also points out that in his study on 300 San Francisco Bay area citizens, people with a hierarchical worldview related themselves towards a moderate and caution personality style, with moderate expectations, associated with a conservative political orientation. In contrast was egalitarianism related to a more confident and forceful personality, expressive and assertive, and associated with a liberal political orientation. I point out on the personality style, because these soft individual factors might find their expression in broader frames like cultural worldviews and biases or political orientation. If the question of 'how' people express their concerns is the key question for risk dialogues (among all citizens (in a globalized world)), then this information can be of more scientific or societal value compared to statistical evidence, expressed for instance in explained variance (R^2). If the question 'what' is highest related to risk perception, then the statistical evidence measures like significance levels or proportion of explained variance are the test criteria.

In his summary on Cultural Theory Renn (2008, 123) points out that empirical studies do observe a relationship between risk perception and cultural worldviews (Langford et al., 2000; Grendstad and Selle, 2000; Bouyer et al., 2001; Rippl, 2002). Many studies, however, show non-significant relationships or only weak correlations (Marris et al., 1998; Brenot et al., 1998; Sjöberg, 2001; Zwick and Renn, 2002). Sjöberg (1995; 2000) repeatedly points to the low explanatory power of Cultural Theory in empirical studies. As a reply to that critique, Susanne Ripple (2002, 162) remarks that the Cultural Theory is a very basic theoretical concept that, by simplifying reality, uses only few basic factors, such as values, to explain the phenomenon of risk perception. If variables that are not embedded in the broader theory of cultural prototypes are used to explain risk perception, such as in the case of the psychometric model, and if both concepts are compared based on this numbers, the argument of explanatory power as quality factor of the theory is hardly to hold.

It is to question whether the Cultural Theory can be perceived as a theory or rather should be treated as a hypothesis and not an empirically proved theory (Renn, 2008, 123). Renn for instance (Renn, 2008, 123) criticizes, in line with other (e.g., Johnson, 1987; Oltedal et al., 2004; Sjöberg, 1995) that the Cultural Theory is characterizing social entities such as organizations and groups and not individuals. If groups cannot clearly be separated in the four or five prototypes, actually the ‘atomized individuals’ as well as the ‘hermit’ are hardly to find organized as a group, reducing the measurable prototypes to three, the problem of falsification arises. Any groups behavior that is observed can be explained by a mix of prototypes. Renn (2008, 123) concludes that on the individual level there is evidence that people tend to be more egalitarian or more entrepreneurial.

In terms of risk communication it is important to adapt the communication style for the people to listen, such as scientists, engineers, business people, environmental activist to communicate the same information across various social entities without creating irritation. In that sense, Renn further concludes, the Cultural Theory is an important concept, because values are taken into the concept of risk perception, broadening the scope of possible explanatory factors. Emphasizing on values and worldviews also enables the observer to imply expressed interests and utility expectations into the broader framework of culturally explanatory factors.

Whether the Cultural Theory is an empirically provable theory or not is a philistine scientific discussion in my opinion, and I hope Paul Feyerabend (1993; 1970) would agree. Maybe the theory’s tautological character, is not a problem, but a merit of this approach and takes the debate about incompatible perceptions of risks a step further. Maybe even closer to a possible solution. If we imagine that societies are somehow connected by cultural boundaries; and if these boundaries comprise what ever exist of social ideas, communication and behavior; if individuals within societies are constantly creating new balances of group cohesion and hierarchical order between cultural clusters and within cultural clusters[48], then whatever is happening within these cultural entities is as such a tautology. In this very abstract notion of a changing social entity, the dynamic is not linear, but a constant flow of action and reaction from the smallest social entity (e.g., an individual signal) to the boundaries of the largest social entity (e.g. the cultural boundaries of social groups). These signals are reflected back by the largest social entity and are perceived again by the smallest social entity; returning the perceived information back to the edges of the system, an so on. In this concept, the ripple effects do not follow a linear dynamic, but ripple back to the core source of signal, and return back to the boundaries of the pond.

[48] This social entities are not closed systems as emphasized by Luhmann’s system theory (Luhmann, 1995; Rosa et al., 2014, 102-109).

Maybe the image of a pond as used by the proponents of the 'social amplification of risk framework' (Kasperson et al., 1988; Slovic, 1987) should be actually changed to the idea of a tea cup. A pond, as an image of an as such infinite entity without boundaries is simply too big to describe a society that is living in an world with defined boundaries. If a drop of water drops in the center of a full tea cup, the ripples go from the center to the cup's edges, return to the cup's center, pass the center and go back to the edges. This concept of the constant rippling effect of water in a tea cup is tautological because it depends of the degree of ignorance, whether a ripple is perceived or not. The degree of a risk's ignorance depends on the individual position in the tea cup – on the individual and social awareness of social change.

A tautological concept allows to perceive the social reality as a reality of constant changes, within given differently shaped social boundaries. The exchange of information across different levels of social and hierarchical organizations might be a modal that enables society to learn and adapt from the constant flow of ripples. If the social correction mode is working, i.e. if the mix of worldviews is balancing the new information, the ripples, as perceived by individuals, should lose its intensity and are not a threat to the social entity anymore. If the ripples are constantly moving from the core of human risk perception (individuals) to the periphery of human risk perception (cultural groups), without losing its intensity, if the social mechanisms of ignorance are not able to create a balance, the society will develop new mechanisms to cope with the risk. Whatever that solution is for the society, it is the best solution a society is able to create within its own structural boundaries. It is a social process.

Douglas and Wildavsky (1983, 194-195) have tried to point to the cultural biases, the cultural lenses that shape each risk judgement. They see their contribution to the debate whether risks are an objective entity or subjectively perceived, by pointing to the fact, that moral and political issues shape the debate about risks. They wisely state: "At any one time there are questions which cannot be formulated, still less asked or answered. But in each generation something can be asked that could not be asked before. Ours has a special experience of other cultures and expertise in assessing cultural bias" (Douglas and Wildavsky, 1983, 195). In terms of technological risks, like nuclear technology, the cultural bias can be expected to be many fold and the debate whether the technology is a source of help or of harm, will echo back and forth in the concert hall of risk perception.

If one sees the Cultural Theory as a theory which only explains group differences beside its terminology that helps to inspire further research, there will not be much power to explain risk perception. Oltedal et al. (2004, 30) point out that individual differences within groups or organizations, as well as similarities among cultures need to be recognized. The authors point out the importance of taking social and cultural group history into account. Historical heritage, influences the level of trust towards hierarchies and authorities within a culture. Since the level of trust, the authors emphasize (citing empirical research by Biel and Dahlstrand, 1995), is related to risk perception, individual's trust in institutions or authorities should be considered as explanatory factor to shape individual's risk perception.

5.2.3. Trust in institutions

In modern societies, trust in social institutions has become an important element for social stability since the number of abstract technical systems has increased, along with the levels of perceived complexity and uncertainty in societies (Giddens, 1990; Beck, 1992). Today most risks are not perceived directly, rather indirectly through social media or other networks. As a result in most cases, external information, provided by social institutions, has replaced individual's direct experience of risks. Social learning processes, therefore, rely on information provided by the information source. Consequently, general trust in the information source is an important factor for an individual's perceived security. According to the complexity reduction thesis (Löfstedt, 2003, 419), the public delegates risks to public authorities, agreeing at the same time to accept the risks judgements carried out by the regulatory agency (Luhmann, 1980). The public on the one hand is dependent on the credibility of the information source and public institutions providing information, while relying on the other hand, on trust and confidence the public expresses to risk agencies. Therefore, successful risk communication and individual risk perception depend on the level of perceived public trust (Löfstedt, 2003, 2005; Breakwell, 2007).

According to Löfstedt (2003, 420), trust in public authorities is characterized by three elements: fairness, competence, and efficiency. An acceptable level of 'fairness' is achieved if the process or the outcome is perceived as impartial. Impartial behavior by the regulator means that everyone's interests are taken into account and the available information is communicated equally to each interest group. The element of 'competence' is the degree to which the agency has the scientific and practical expertise to meat all criteria to best deal with the process. 'Efficiency' is the perception that the agency is not wasting public money being in charge of the risk, but is spending taxpayer's money for the best possible processes and outcomes. Beside these three elements of trust, Renn (2008, 124: Table 4.7) emphasizes five more elements as constitutive components of trust: objectivity, consistency, sincerity, faith, and empathy (see also Barber, 1983; Lee, 1986; Slovic, 1993). 'Objectivity' is a bias free information procedure performed by the agency and perceived by all parties. 'Consistency' is the element that expresses how predictable an agency's performance is, given past experience and previous communication procedures. 'Sincerity' is the degree of honesty and openness. The element of 'faith' is the perceived goodwill of an agent regarding its performance and communication style. 'Empathy', the fifth element, is an agent's ability to be aware and to understand the feelings and expectations of other parties and to respond in an respectful manner. These combinations of elements of trust are assumed to balance out negative public feelings about a complex and uncertain environment.

In social science research on risk perception, trust in institutional performance is expected to be an important explanatory factor for risk perception, particularly in cases of risks that are perceived as very dangerous, dreadful, and unfamiliar. In these cases individual's trust in social agents can countervail doubts and, hence, is balancing negative risk perception. In the case of distrust, even negligible or small risks can be perceived as very dangerous, resulting in considerable ripple effects. This asymmetric effect of trust and distrust has been observed in various studies (e.g., Siegrist and Cvetkovich, 2000; Siegrist et al., 2000; Cvetkovich et al., 2002; Viklund, 2003).

Because trust is an important factor for governing and manage risks in a modern society, the asymmetric forces of distrust can substantially influence social practices. As Parson (1960) points out, trust on the aggregated level is a generalized medium to enable social differentiation. To enable social differentiation through different social agencies, people a-priori pronounce trust to the risk managing agency, enhancing a society's efficiency and economic performance (Fukuyama, 1995). Modern societies, therefore, rely upon the trust and credibility of its members: "The reliance of technological society on trustful relationships between and among subsystems has never been stronger than today" (Renn, 2008, 126). Renn (2008, 125) furthermore remarks that empirical studies indicate a decline of trust in political institutions, industry and also in science, compared to trust levels in the 1960s (Löfstedt, 2005; Siegrist and Cvetkovich, 2000; Siegrist et al., 2000).

A variety of studies indicate that higher levels of trust in risk managing institutions result in lower risk perception (Kunreuther et al., 1990; Bord and O'Connor, 1992; Flynn et al., 1992; Slovic, 1993; Biel and Dahlstrand, 1995; Jungermann et al., 1996; Cvetkovich and Löfstedt, 1999; Siegrist and Cvetkovich, 2000; Wachinger et al., 2013). This negative effect of trust can be observed particularly for nuclear risk perception and trust in nuclear risk managing institutions. Cross-national studies in Western-Europe and the United States for example, on the relationship of risk perception and trust show that the levels of trust vary between countries (Viklund, 2003; Slovic et al., 2000a).

Viklund (2003) also remarks that the relationship of trust and risk perception varies between general and specific trust[49], and that the relationship depends on the type of technological risk that is managed by an entrusted agency. In case of nuclear risk perception, expressed trust in an authority to protect against nuclear risks relates clearly to the perceived risk. In Sweden and France, trust in a specific agency, such as the national nuclear energy authority, is a factor influencing nuclear risk perception; however in the United Kingdom, only trust in national government could be observed as predictor for individuals risk perception (Viklund, 2003, 736). A cross-national comparison of

[49] Trust usually is operationalized as the degree to which people agree or disagree on a statement on how trustworthy respondents perceive other people or institutions (general trust) or how authorities help to protect citizens (specific trust) (Viklund, 2003, 730). For example, specific trust of expert's knowledge on nuclear power was operationalized by Slovic and colleagues (2000a, 88) by asking: "We can trust the experts and engineers who build, operate, and regulate nuclear power plants." Respondents in the U.S. and French sample could decide to "Strongly disagree", to "Disagree", to "Agree", or "Strongly agree" to the statement. General trust in the International Social Survey Programme 2010 (ISSP, 2012) is operationalized as a question: "Generally speaking, would you say that most people can be trusted, or that you can't be too careful in dealing with people?" Respondents can choose a value between 1 and 5 on a scale with the limits of "You can't be too careful" (scale 1) and "Most people can be trusted" (scale 5).

nuclear risk perception in the U.S. and France by Slovic and colleagues (2000a) further indicates that different levels of trust exist between societies, even though the levels of nuclear risk perception do not differ much in both countries. In their study, French respondents had greater trust in the credibility and competence of their nuclear risk authorities, as well as nuclear industry, compared to the U.S. counterparts. French respondents also expressed greater trust in experts' behavior, favoring experts rather than the public to decide about the necessary steps in managing nuclear risks. Slovic and colleagues therefore conclude, that different "democratic models" (Slovic et al., 2000a, 57) are shaping individual's acceptance of technological risks. French respondents, even if they believe that they have little control over the risk, express trust to experts and authorities to control the risks, whereas in the U.S. respondents express more skeptical views about their risk managing authorities. In my empirical work in Section 6 I will discuss differences in nuclear risk perception and the role of trust in France, the U.S., the United Kingdom, Germany, and Japan again in more detail.

In the case of unfamiliar and complex risk technology, such as nuclear power, trust matters. The knowledge individuals express about a familiar or unfamiliar technology can be an explanation for different levels of trust regarding different technologies. Siegrist and Cvetkovich (2000), as well as Sjöberg 2002 found support for the hypothesis that an increased knowledge about a risk is weakening the relationship of trust and risk perception regarding that specific risk. The level of trust for a technology is, as Sjöberg (2001) assumes, a signal of ignorance or uncertainty. Renn (2008, 126) argues that laypeople's judgement of a risk agent's credibility depends on the perceived uncertainty that is associated with a specific risk. The (un)conscious feeling of ignorance, as I conclude, can find its expression in the levels of perceived trust, when judging a risk. Hence, trust in public authorities and institutions might be an indicator of an ambiguous feeling of ignorance or uncertainty and of an imbalance of security and control towards a specific risk within a society.

The asymmetric relationship of trust and risk perception puts the risk managing agency in an unwanted predicament. A single mistake can evoke suspicious doubts and can destroy public trust in risk managing institutions immediately without warning signals. Since trust can easily be destroyed, but is hard to gain back, a destroyed balance of trust between risk takers and risk bearers is able to provoke public action, like protests, against a risk or its risk managing authorities (Bord and O'Connor, 1992). In contrast, as Renn (2008, 126) argues, risk's seemingly stochastic nature can also cover up for all management mistakes or any forms of mismanagement by referring to the randomness of an unexpected event, like a nuclear accident.[50]

[50] The risk entrepreneur might reflect: 'Due to the inherent ignorant nature of human beings, the stochastic error can always be blamed to be the evil; and to some degree this blame is always justified, because of the stochastic nature of life on earth – wait, who wants to control the stochastic nature of life on earth? Right, ignorant human beings and its various forms of social organizations. She or he is getting into an infinite regress and the reflection is turning into a tautological explanation of what risks and its risk communication processes might be.

Risk managing agencies are continually forced to legitimize their action or inaction in case of an unwanted event. Even though in most cases, single events do not prove management failures, they are able to change the public perception of a risk. If the balance of trust among all parties is destroyed or tainted the consequences of an event can ripple through society having long lasting effects on laypeople's perception of a risk source and its risk managing institutions.

Studies on trust in public agencies (e.g., Kunreuther et al., 1990; Slovic et al., 2000a) for instance, indicate that the decline in nuclear risk perception for the U.S. relates to an increased distrust in the domestic atomic regulation authorities, a "crisis in confidence" as Slovic (1993, 676) states. The crisis in confidence as observed in the U.S., can be hypothesized, to still be related to a single negative event, like the nuclear accident at Three Mile Island (e.g., Slovic et al., 1984, 470). Slovic (1993, 679) argues that initial trust or distrust influences how people perceive a negative event and reinforce initial or a-priori beliefs and perceptions. People, distrusting nuclear power prior to the accident, interpreted the accident's outcome as a situation where luck is what avoided a melt down and a catastrophic disaster for all parties involved. In contrast, people, trusting the technology a-priori, perceived the accident as a demonstration of how the safety procedures functioned in the expected way; the accident as an example of how well the system could be controlled by the agents in charge of the risk.

A study by Nakayachi (2015) in Japan, tested the hypothesis that after the 2011 Tohoku Earthquake and its devastating consequences for the population and economy, public's trust in official authorities and risk managing institutions, decreased across all institutionalized risk areas. The author calls the effect the "contagion hypothesis," hypothesizing that the general trust level in experts' expertise is expected to decrease and spreading in unrelated risk areas rippling over the boundaries of the original disaster (Nakayachi, 2015, 58). The study could reject this hypothesis. A comparison of trust levels across 51 risks and technologies, using cross sectional data from two representative samples in 2008 and 2012, showed that trust levels for risk areas of 'earthquakes' and 'nuclear accidents' did, as expected, significantly decrease The trust level of 30 out of the remaining 49 risks did not change and in 19 cases the levels of trust in 2012 were significantly higher than in 2008. The author concludes that while a spread of distrust seems to be plausible after a major disaster, what occurred in Japan was a "seesaw effect" or a contrast effect (Nakayachi, 2015, 60). This contrasting effect indicated that population's worries were sensitized to the risks of earthquakes and nuclear power, whereas their concern for other hazards diminished. The author's critical remark is that the shift in public trust, with higher levels of trust for other public institutions, is able to create a culture of comfort which ignores or disregards other hazard's catastrophic potential.

Wachinger and colleagues (2013) point towards the negative side effects of high levels of public trust. High levels of trust, as they assume, lower public risk perception as well as decrease public's preparedness for unexpected or long-term hazards. In his overview on studies on safety culture in organizations, Conchie and colleagues (2006) also remarks that trust is a multidimensional concept. The authors distinguish between trust, distrust, and creative mistrust. An organization's safety culture that is based on trust and creative mistrust, according to the empirical results, turned out to be most effective for the safety of all parties. In that sense I conclude, that if trust is perceived as a level of ignorance in society, high levels of trust, in any authority, do not reflect realistically the levels of non-knowledge that exist due to the stochastic nature of risks. Any risk assessment processes that are designed to eliminate uncertainty, hence, also create an artificial atmosphere or 'zeitgeist' of trust and are deliberately peculating public's credit of trust. A well designed risk assessment, I think, takes the different dimensions of trust into consideration and creates an atmosphere of distrust and creative mistrust in order to create, through constant listening and questioning, the best available risk solution for all affected parties.

5.3. Sociodemographic factors shaping risk perception

5.3.1. Gender roles

I will now turn to reflect the effect of gender on risk perception with the focus on nuclear risk perception.[51] When talking about the gender differences in risk perception, I first introduce the socialization approach, explaining gender differences by the socialized role of being a woman or an man in society. I then explain in more detail five hypotheses that have been put forward to explain gender based differences in environmental risk perception. In a next step, the theoretical explanations will be confronted with empirical results of mostly quantitative risk perception research. The empirical research will be classified in three categories: a) overall environmental concern and general risk perception research; b) specific risk perception, especially nuclear risk perception research compared to non-nuclear risk perception research; and c) risk perception research on local and (site-) specific level compared to broader levels of concern.

As will be shown, the gender differences vary depending on the category of risk perception. I am not able to give a complete overview of the entire empirical research that has been done in that field. The main geographical focus will be on research in the U.S. complemented by cross-national research, since Boholm claims that the "effects of gender vary cross-nationally" (Boholm, 1998, 150). I finish this section by emphasizing that a person's self-identity can also be understood as a concept of self-perception representing itself in categories such as 'femininity' and 'masculinity'. This categories of self-identity are a threshold for perceiving the world rather than the actual and physical gender.

Regarding concerns about environmental and technological risks, women have been observed to consistently express higher risk perception in comparison to men. A closer examination of the theoretical explanations, that have been put forward so far, indicate

[51] In this part I rely to a great extend on an excellent study done by Davidson and Freudenburg (1996).

that the underlying social mechanisms are more complex and intertwined than the obvious biological differences of men and women would suggest. It does not seem to me that risk perception can be divided in a dichotomous sphere of male and female perspectives.

Differences in the socialization process of women and men are an obvious explanation for why humans develop different roles in their social environment (e.g., Chodorow, 1978). From a Western perspective and accepting the Western nucleus family model as the standard social entity of socialization, female children, identifying with their mothers are assumed to develop a relational perception whereas male children, observing the role of their fathers, are assumed to develop a controlling role. The theoretical explanation suggests that because male children are different than their mothers, they are able to objectify themselves and the world around them. As a result, boys develop a distant relationship to their environment and the desiring to control this distant, relational, and objectified relationships. Men identify themselves in relation to their environment. Women, in contrast, identify themselves as part of their surrounding environment and their community.

Davidson and Freudenburg (1996, 305) critique this explanatory approach, as too narrow and too closely related to the Western family model, perceiving the female role as the homemaker and caretaker and the male role as the breadwinner and provider. Yet the authors remark, that even if the standard family model does empirically not exist anymore because, for example, of single parent families or women in both roles as breadwinner as well as caretaker, the role image still exists in society and is reproduced by its social institutions and social practices. The self-identification process based on role expectations therefore still influences individual choices regarding education, occupation or parenting, the authors conclude.

An individual's socialization process itself should also be reflected in the attitudes towards science and technology and be measurable in different responses towards technological risks for society. According to the socialization or role model approach, attitudinal differences between men and women should be explained by different roles, related attitudes, and derived risk perceptions practiced over generations. According to this approach, men are expected to perceive themselves as more knowledgeable about technology and social development, expressing higher levels of trust in social institutions. Historically, men have been involved in creating and self-recruiting scientific and technological institutions. These male dominated domains of society can be assumed to be essentially or 'holy' for male's self-identity. Ideal Western role-model men are expected to defend their self-identity and by that their holy cows, manifested, for example, in beneficial technological industries, efficient management procedures and scientifically proven knowledge claims. Men as the assigened family providers are expected to express higher concerns for economical development than for environmental consequences of human behavior. Typical role-model women, to the contrary, are expected to focus on their family's and community's health and safety. With this assumption, women are expected to express higher concerns to environmental problems or technological risks when risks are perceived as a health and safety threat for a specific social entity, such as their families, local communities, or the world.

In their theoretical overview, Davidson and Freudenburg (1996, 316) identify five major hypotheses that can explain differences in risk perception between gender. It is also a scheme for classifying existing empirical research on the assumed gender gap. The first and second aspect are the hypothesized differences in knowledge and trust in institutions; the third hypothesis focuses on the concerns for economic development; the fourth and fifth aspect, regard safety and parental concerns as drivers for differences in risk perception.

The authors go on to identify three categories or dimensions of risk perception studies to test their hypotheses. The first dimension of studies are general attitude surveys, which do not ask about a specific environmental risk. The second type of studies are studies examining specific environmental attitudes. This category includes studies explicitly designed to test attitudes towards nuclear energy or nuclear waste, while studies evaluate individual's risk perception of environmental issues that are not related to nuclear, such as acid rain, toxic waste or contamination, genetic engineering, or genetically modified foods. The third area are studies evaluating environmental concerns about local or site-specific issues or non-site-specific environmental risk issues with a regional, national, or global scope of interest. Given that wide spanned dimensions of empirical research, the expected gender differences can be tested across different areas of concerns.

The empirical results show (cf., Davidson and Freudenburg, 1996, Table 1: 311–313) that the gender effect is most pronounced for nuclear issues, with women expressing higher concerns for both site-specific issues and non-site-specific issues (e.g., Nelkin, 1981; Brody, 1984; Slovic, 1999). In studies related to non-nuclear risks, women tend to show higher risk perception. The differences in risk perception are stronger if the environmental issues, such as toxic contamination, are site specific. Qualitative studies on local environmental issues reveal that women often are in a leadership role and take responsibility for improving the situation and opposing for instance local waste storage sites (e.g., Levine, 1982; Freudenburg and Pastor, 1992). Davidson and Freudenburg (1996, 316) also remark that observable differences differ in their actual or measurable statistical strength. The consistent findings regarding environmental issues, such as nuclear energy or local toxic contamination, are also statistically strong. Broader questions on environmental concern do not only show inconsistent results of the direction of the gender effect, the observed differences are also not very strong in the measured scale, most often measured in percentage points.

Five hypotheses or directions of explanation have been put forth to explain gender differences in environmental risk perception. Davidson and Freudenburg (1996, Table 2: 320–321) call them: 1) the "Knowledge Support Hypothesis" , 2) the "Institutional Trust Hypothesis" , 3) the "Economic Salience Hypothesis" , 4) the "Safety Concern Hypothesis" , and 5) the "Parental Role Hypothesis".

The first hypothesis, the "Knowledge Support Hypothesis" (Davidson and Freudenburg, 1996, 317-319) assumes that men, in contrast to women, are more knowledgeable about existing environmental risk issues. It is assumed that people who are more informed about risk issues will be less concerned about a risk's assumed negative outcomes on safety and health for society and environment (Kuklinski et al., 1982; Lopes, 1991). Empirical results in the Davidson and Freudenburg review show that on average men are more knowledgeable about a risk's technical details, supporting the first assumption of the Knowledge Support Hypothesis. The second assumption of the hypothesis cannot be confirmed empirically. The assumed relationship that more knowledgeable people perceive less concern about environmental risks has been rejected in many studies. The relationship even differs in its direction, indicating that people who oppose a technological or a site-specific environmental risk are better informed than a risk issue's proponents (Arcury et al., 1987; Solomon et al., 1989). In the case of the Love Canal (New York) toxic waste disaster for example, local activists, mostly women, opposing a controversial risk were better informed than its local supporters (Fowlkes and Miller, 1987).

A study by Kuklinski and colleagues (1982) furthermore examines the relationship between knowledge and political ideology among American citizen. The core values that people invoke on their decision making processes about nuclear energy issues differ among informed and uninformed people. The authors find that better informed individuals invoke core political ideological values, such as being liberal or conservative in their decision-making process, whereas uninformed people invoke values that are not related to their political ideology. Less informed people also tend to seek advice within their social groups, whereas " knowledgeable citizens felt no need to take directional cues from groups" (Kuklinski et al., 1982, 633). Ideological and traditional values are core features influencing judgements of unfamiliar environmental risks and evaluating uncertain policy choices. This effect is stronger and more pronounced for better informed people. Less informed people tend to rely more on core values that are not related to their political ideology, allowing them to accept different opinions provided by groups. These results pertain to citizens of the United States and to research results in the United Kingdom (Costa-Font et al., 2008).

In their conclusion about the Knowledge Support Hypothesis Davidson and Freudenburg (1996, 318-319) advise rejecting the hypothesis or scrutinizing the results and the operationalization of a study with scientific skepticism because the evaluated empirical evidence differs in its direction. More studies are even pointing in the unexpected direction of higher expresses concern associated with higher levels of knowledge.

The second hypothesis, the "Institutional Trust Hypothesis" (Davidson and Freudenburg, 1996, 319), reveals a clearer empirical pattern, with high levels of empirical evidence in the United States, supporting the hypothesis (Freudenburg, 1993; Flynn et al., 1992; Fox and Firebaugh, 1992; Slovic, 1999; Bella, 1987; Slovic, 1993; Rayner and Cantor, 1987). The hypothesis holds that men in contrast to women tend to have more trust in institutions, especially in governmental, scientific, and technological institutions. It is furthermore assumed that there is an inverse relationship between trust and risk perception with the expectation that respondents expressing higher levels of trust will express lower environmental risk perception.

Empirical results do indicate that women tend to trust institutions less than men and express higher levels of concern, confirming the expected negative relationship. An aspect that is part of the observed gender gap related to trust in scientific institutions is, as indicated in a study by Hornig (1992), that female respondents see higher risks and less benefits in scientific development. A study by Hamilton (1985) on toxic waste in local communities indicated that women with children not only express higher levels of concern, but are also more active in organizing opposition and in questioning public authorities. Since most studies that Davidson and Freudenburg (1996, 319) examine show the expected negative relationship between trust in institutions and technological risk concern, and find that women tend to trust authorities less, the Institutional Trust Hypothesis hypothesis cannot be rejected. The results even indicate that, at least in the U.S., trust in institutions is a factor that cannot be neglected when explaining observed gender difference in environmental risk perception.

The third hypothesis the "Economic Salience Hypothesis" (Davidson and Freudenburg, 1996, 322) assumes that men, compared to women, are more concerned with economic issues. It is also assumed that individuals who are in the labour force, independent of their sex, are likely to be more concerned about economic issues. The hypothesis assumes that there is an inverse relationship between economic concerns and environmental concern, indicating that individuals expressing higher concerns regarding economic issues are more likely to express lower concerns on environmental risks. The Economic Salience Hypothesis is in its conception not a pure gender specific hypothesis because it incorporates the interaction of gender and employment status on risk concerns.

In a study by Stout-Wiegand and Trend (1983), the authors assume that economic concerns among men are the reason for observed lower risk perception among men. Among men and women working in energy-related industries, women who expressed higher levels of environmental concern where also more skeptical about technological developments compared to their male colleagues. Male colleagues expressed less concerns about future energy developments, independent of their levels of environmental concern. Men and women not working in an energy-related industry did not show gender differences. This results indicate that men in the workforce, who are more concerned about the economy, are more enthusiastic about future developments, independent of their environmental concerns. Studies comparing environmental risk perception among full-time employed men and women showed that on average women express higher levels of environmental concerns compared to men (Mohai, 1992). Additional empirical studies focusing on the employment status and risk perception indicate that with full-time employed individuals, both men and women tend to express higher levels of environmental concern (Blocker and Eckberg, 1989).

The Economic Salience Hypothesis cannot be confirmed because empirical studies provide mixed results. The gender gap should be independent of the employment role an individual has in society. Factors other than economic concerns or the idea of being a family provider should be considered in order to explain the gender gap. One approach is to identify the source of a risk more accurately. For instance, Stern and colleagues (1993) find that women perceive nuclear technology as an environmental problem whereas men tend to see it as a technical or scientific problem.

The fourth hypotheses identified by Davidson and Freudenburg is the "Safety Concerns Hypothesis" (Davidson and Freudenburg, 1996, 323). The hypothesis assumes that women in comparison to men rank health and safety issues as more important. This relationship should be expressed in higher levels of environmental risk concerns among women, especially when risks are exposed to the family or the local community. Among the five hypotheses taken into consideration, the Safety Concerns Hypothesis receives the clearest support. All the examined studies (cf, Davidson and Freudenburg, 1996, 321: Table 2) show consistent support for the hypothesis (e.g., Brody, 1984; Solomon et al., 1989; see also Greenberg and Schneider, 1995; Forbes and Sells, 1997).

The empirical findings support the theoretical explanation that women created a higher awareness for safety and health issues because of their social role as care provider and nurturer. For future research, the authors encourage and propose to test this theoretical explanation by analyzing women's and men's employment status in relationship to both of their roles in the household. Then the combination of the role of economic provider (the Economic Salient Hypothesis) and the role as caretaker (the Safety Concerns Hypothesis) is able to shield new light to the complex structure of worldviews, social roles and institutionalized power structures in society that interplay and create differences in risk perception – differences that then are labeled gender gap. The term gender in that case serves as a marker for social mechanisms that created and are still creating these differences, mechanisms which have not yet been revealed.

The "Parental Role Hypothesis" (Davidson and Freudenburg, 1996, 325) holds that children at home will have opposite effects for women and men. Women in the role as mothers and care providers will express more concerns regarding health and safety issues (compare the Safety Concerns Hypothesis), whereas men in the traditional role as fathers and economic providers will express higher levels for economic issues and lesser concern about technological or environmental issues (compare the Economic Salience Hypothesis). Empirical results for that hypothesis in the United States show mixed results and do not support the hypothesis in its purity. For instance, studies by George and Southwell (1986) as well as Blocker and Eckberg (1989), show that men's support for a new industrial development such as a nuclear power plant is higher among fathers. Other study shows that fathers in comparison to men without children, express higher concerns for local toxic contamination (Hamilton, 1985). Women with children were identified as the most concerned group supporting the Safety Concerns Hypothesis. A resent study by Simon (2013) supports the assumption that parents express greater concern for nuclear risks. The analysis showed that women who lived with children were more likely to show lower support for nuclear power compared to women not living with children. In this study mothers compared to fathers also expressed higher concerns on nuclear issues, supporting the Parental Role Hypothesis.

The mixed results for the Parental Role Hypothesis, as well as for the Economic Salience Hypothesis indicate that traditional sex roles are changing or are a theoretical artifact. The comparably strong support for the Safety Concerns Hypothesis and the Institutional Trust Hypothesis indicates that women and men differ in their perception of social reality and on their perception of the environment. Women seem to show a greater awareness for the health of the environment. Men in contrast express a greater awareness of the power structure of their environment. In my opinion in both cases different ideas or feelings of responsibility seem to be the energies that create a gap in risk perception.

A core catalysts of the gap is knowledge or an individual's self-assessment in the existing or accepted knowledge structure. Those who assess and created, and reproduce, the existing knowledge structure and the educational system, perceive themselves as more knowledgeable. If knowledge is seen as a factor to eliminate error or uncertainty, hence a mean of power to diminish risks, a knowledge structure that provides ideologies that explain uncertainty and reduce error is able to reduce risks. Those in society who are assumed to be more knowledgeable, therefore should be express lower risk concerns. This assumed result can be found in empirical research as shown above. The empirical findings also show the opposite results, indicating that those who are expected to know more are also more concerned. The Knowledge Support Hypothesis does not hold because the empirical test shows mixed results.

Flynn, Slovic, and Mertz (1994) suggest taking into consideration broader shaped value concepts incorporating power, status, equity and trust, or alienation to identify societal subgroups that are distancing themselves from society by expressing very low levels of risk perception. In their study on environmental health risks, the authors observe a gender gap with men expressing lower levels of concern. Controlling for sociodemographic factors among men, a subgroup of white men is identified that expresses very low levels of technological risk perception. These subgroup is also characterized to be better educated, having higher incomes, and were politically more conservative. These white men also tended to express greater trust in government and authorities that manage technological risks. Beside these factors white men are also more likely, on average, to be less concerned about the poor and to be more willing to impose risks on people in society without consulting them or asking for any agreement.

Flynn and colleagues (see also Boholm, 1998, 151) argue that the observed white male effect counts as an example which proves that an approach that tries to explain the observed gender gap referring to biological differences between women and men is insufficient. The empirical results speak against a biological explanation for risk perception and the gender gap should be more or less equally distributed across biological and social stratification as well as across ethnic or cultural boundaries. The historically grown social experience among subgroups in society, independent of their sex or biological 'equipping', should also be considered to be relevant to explain gender differences. Observing a subgroup of extreme responses, such as in the case of white men in the U.S. expressing very low levels of risk perception, indicates that there is a bias towards greater acceptance.

The reasons for this skewed distribution among American men could be hypothesized by referring to the social role that subgroup had played in society in the past. White men were in charge of institutionalized social life and have been controlling, managing, and benefiting from the system they took care of. Higher levels of income and education are an indicator for the higher status they gained over time. The subgroup's knowledge and familiarity with the system makes the individuals of that subgroup to perceive some risks, such as environmental or technological risks, as less risky in their cost/benefit calculation. Technology and nature seem not to be a threat for white male's ideological and biological existence on earth – maybe more complex social issues like sharing power, ideologies, and goods are perceived as a risk. Beside the reported study by Flynn et al. (1994) the white male effect in the United States was also found and discussed in more resent studies such as by Finucane et al. (2000b) and McCright and Dunlap (2011).

The gender gap, I conclude and hypothesize, is a 'gender' gap within the subgroup of men. What creates the lack of error, the ignorance of ignorance, is an identity that wants to control someone's changing world based on explanations, rather than understanding, trusting and not feeling responsible, and accepting rather than questioning. In this sense institutionalized science is trying to teach the world and its members that the world can be explained by accepted principles and we can trust the underlying assumptions. What the world is trying to teach institutionalized science and its members is to question the underlying assumptions and to accept that the world in its complexity and inherent mechanisms cannot be explained. Science is not an art of questioning, science has become a tool which serves to explain and rationalize. These subgroups in society that still are able to question will be able to change the world without using the force of their hands, but the words of their ideas. The observed gender gap indicates that there are different ideas in the world, of how to perceive and to govern risks in social environments.

5.3.2. Masculine identity

The relationship of identity and risk perception, is not a factor to be neglected in order to build a broader understanding of gender's risk perception. Kahan and colleagues (2007) argue that activities are perceived to have lower risks if they play an important part in reinforcing someone's cultural identity. In that sense, risk judgements can be interpreted as a way to reinforce core values and cultural norms that individuals believe in. The authors even go so far as to talk about an "identity-protective cognition" (Kahan et al., 2007, 465), such as the above mentioned white-male effect. In a study of adolescent boys, for instance, behavior useful to prove their masculinity was judged as less risky (cf., Reardon and Govender, 2013, 753-754). The aspect of masculinity may not turn out to be the most important aspect in analyzing nuclear risk perception or risk perception. Nevertheless, I have chosen to include this theme in my dissertation in an attempt to understand more about how socially constructed role-models are reproducing views that shape the way individuals perceive their environments through communication and behavior. I am especially interested in the aspects of what is called traditional masculinity or hegemonic masculinity.

In literature on masculinity, traditional or hegemonic masculinity is used to describe a particular type of masculinity that is in the dominant position and able to reinforce the legitimate order of patriarchy in society (Reardon and Govender, 2013; Connell, 1993, 1995; Donaldson, 1993). This dominant position allows members of the traditional masculine subgroup to stay in power, to define and impose norms and ideals for on the whole of society. It is assumed that in return for their contribution in keeping social law and order, the patriarchs receive a patriarchal bonus. This entails that beside the material bonuses, such as higher income or better opportunity structures in institutions, the "patriarchal dividend" is also payed off in immaterial privileges such as honor, prestige, and authority (Reardon and Govender, 2013, 754). These different privilege structures are reinforced by different subgroups in society. Since almost all men have built on this patriarchal structures it is assumed that men have the tendency to try to maintain the given order.

The theoretical concept of hegemonic masculinity assumes a negative effect on individual's risk perception if the risk is threatening resources or means of defending masculine identity and the patriarchal dividend. Presuming this relationship is correct, risk judgements of inequality issues, technological development, environmental change, contamination or pollution, violence, national conflict and global development should correlate with perceived masculinity. Technological or environmental risks are often the consequence of social developments, technological developments, or institutional developments that were created to defend the dominance of one specific type of masculine identity, protecting and reproducing a hegemonic type of masculinity. The traditional form of masculinity, as Reardon and Govender (2013, 756) conclude, should not only be related with higher acceptance levels for hazardous technologies such as nuclear power or higher acceptance of bellicose decisions, it should also be related to adverse health and safety behavior on the individual level, such as alcohol use, unsafe sexual practices, and dangerous driving.

Empirical studies indicate that men who try to separate from the hegemonic masculinity, representing "progressive masculinity" (Reardon and Govender, 2013, 756), are expressing higher levels of concern for environmental risk and inequality (cf, in the case of South Africa Reardon and Govender, 2013). This group of men is also more easily to mobilize for environmental movements (Connell, 1990). Reardon and Govender support the hypothesis that men in South Africa identified as traditional or hegemonic masculine, are more likely to support activities that are associated with the core masculine norms such as "toughness, risk-taking, bodily strength and invincibility" (Reardon and Govender, 2013, 765). The authors compare the interaction of types of masculinity and the cultural prototypes as described above in the chapter of Cultural Theory (compare Section 5.2.2). Empirical results in South Africa indicate that hierarchical worldviews are related to the hegemonic masculinity type and related to lower environmental risk perception. The hierarchical order with its firm segregation and classification of age, race, and class structure within society (Wildavsky and Dake, 1990; Dake, 1991; Douglas, 2003) and its means of social control and subordination, is closely linked to the patriarchal power structures that are based on the idea of inequality and gender differences. In contrast to the hierarchical prototype, the egalitarian worldview correlated with the anti-hierarchical type of masculinity, both related to higher environmental risk perception.

The combination of cultural worldviews and gender differences might be a useful approach to open the discussion to the conflicts among subgroups in society such as women and men within certain cultural entities or the conflict of men and men within a given social entity, for example the conflict between different generations. Individual risk judgement, I hypothesize, could be an indicator of hidden and deeper conflicts within societies and different subgroups and cultures (Tansey, 2004). In a qualitative study in Japan with in-depth interviews, Morioka (2014) tried to identify the influence of political and economic institutions on men's risk perception focussing on the mechanisms of how these institutions reproduce a hegemonic capitalist and masculine ideology of self-identity. Morioka judges sharply concluding that "the 'mechanisms of self-identity' including masculinity shaped by modern institutions play a critical role in risk society. The consequences of narrowly defined manhood can be unexpected, far-reaching and damaging" (Morioka, 2014, 111). Her judgement is based on qualitative interviews in the aftermath of the Fukushima disaster in 2011 comparing the risk perception of nuclear radiation between both sexes. Men, including fathers, tend to express lower risk perception compared to women and mothers. Men's interpretation of the risk, as observed by the author, is to perceive radiation as a threat to financial stability and not to own health or the family's well-being. Norms, imposed or performed at work, played an important role to ignore the potential threat of the actual risk as well as the concerns expressed by women and spouses.

An other observable mechanism of ignorance was self-censoring and not expressing concerns at work, so as not worry colleagues. Respondents reported that they felt badly touching someone's feelings, by expressing concerns. The prevalent norms of silence and denial, as seen in powerful economic and political institutions serve its members as identity-protection mechanisms as well as justification of the system against critiques (Morioka, 2014, 110).

The author concludes that the nuclear fallout in Japan can be interpreted as a threat to the hegemonic masculinity structure in society and its institutions. Men's lower risk perception can be interpreted as a defense strategy to defend the existing system they have created and work for and believe in. The author explains that the Japanese system is built on the principle of economic supremacy (kei-zai-yusen-shugi). In that case, denying or ignoring a risk and taking action against someone who expresses risk concerns is an expected consequence, such as in the case of employed husbands who get angry in conversation with their concerned spouses. The interviews revealed that husbands believed in the information structure that existed in their place of work, perceiving colleagues as reference points, and following the work norm to adjust to others. In the sense of the social amplification of risk framework, in the case of Japan, the institutions mediated as a diminishing factor attenuating the risk and avoiding ripple effects. The sexual division of labor, helping to create a functional family turned out to be dysfunctional in the case of the nuclear accident. Men expressed lower risk perception while being part of the more powerful workforce lead to decisions that brought family members, especially children in danger. Whole families did not leave the contaminated area because women did not want to or were not able to leave the area without their husbands. Men preferred to stay with the status quo, prioritizing work over health questions, sticking to their masculine identity as breadwinner (Morioka, 2014, 109).

The radiation risk of Fukushima is one example of an environmental risk that societies can be confronted with. The new situation after the risk could lead to fundamental changes for the whole society. In that sense risks and their unpredictability can be a challenge, as in the case of Japan, to the foundations of society if the system is built on values and norms that created the risk (Feygina et al., 2010). Morioka points out that anti-nuclear activists, challenging the existing system in Japan, tend to be people who are not part of the workforce, such as students, freelancer or retirees (Morioka, 2014, 110).

In the case above of hegemonic masculinity, the ideology is designed to avoid change and to maintain the existing structures of inequality. The inequality between gender and race, the capitalist system, imperialism and global inequality are reproduced by the existing social structure (Connell, 1993). The inequality structure is based on hierarchy and power. Connell makes the point that in the tradition of European masculinity, from his point of view, the first group identified as masculine were the conquistadors, a group of men, segregated from society, defining themselves as soldiers and sea traders, not to be controlled by a state authority (Connell, 1993, 607). According to Connell, the actual institutionalized foundation of masculinity in European/American society took place during the dynastic wars in the seventeenth and eighteenth century. Masculine power got institutionalized in the establishment of a strong national state structure at that time. One core element of state construction and hegemonic masculine gender order was the role of military and military values: "The centrality of warfare in these developments meant that armies became a crucial part of the developing state apparatus, and military performance became an unavoidable issue in the construction of masculinities" (Connell, 1993, 608). Hence, masculinity became the dominant gender order in the class of gentry, a powerful class of people in European and American society, dominating the military apparatus of a state at that time. Masculinity was based on a code of honor and a willingness to take violent action against an opponent. The duel, as the most honorable one-to-one combat, turned out to be the proof for gentry masculinity.

During industrialization and political revolutions, the state apparatus became more rationalized and masculinity more regulated. The Prussian officer corps is a good example of a code of honor combined with an bureaucratically rationally organized violence apparatus. The superiority of industrialized weaponry and war science enabled European countries and its political, military, and economic institutions in the nineteenth century to colonize most parts of the world. Allowing the hegemonic masculine type of men to be the hegemonic type of a man. Tendencies for social change before and at the end of World War I did challenge the hegemonic masculinity resulting in more radical forms of masculinity, like fascist movements in Europe, glorifying the irrationality of violence, inequality and superiority. The victorious armies after World War II, the Red Army and the U.S. armed forces stopped fascism but continued to grow in a destructive quantity, establishing a "bureaucratic institutionalization of violence" (Connell, 1993, 609). During the Cold War technical expertise became an important core element of masculinity, in addition to the military code of honor and violence as a mean to maintain order, because scientific expertise became more and more relevant to the development of economic growth and more importantly to the development of weapons that guarantee military superiority.

Industrialization also changed the family structures, allowing men to separate from family life, establish a working class, be the breadwinner and the domestic patriarch, and to organize themselves in unions. As a result, masculine ideals became the dominant culture in the broad population and not only in the nobility or gentry of society.

More recently in the 1980s, according to Connell, the entrepreneur in business has emerged to be a new form of masculinity. This generation of entrepreneurs, mostly in finance industry, uses a language that is full of gender and military terminology, terms such as "trusting entrepreneurs, opening up virgin territory, aggressive lending, etc." (Connell, 1993, 614). Not only in business schools, but also in risk assessments the language used to talk about solving risk problems is also based mostly a masculine, i.e. based on a military jargon of dominance. The historical picture I have tried to depict in order to describe the concept of masculinity, is obviously based on a thin empirical evidence (cf., Connell, 1993, 619) and is a hypothesized recourse back to some historical developments that could have been potential influences shaping the existing gender differences, observable in today's society.

I want to close my observations on gender differences and the concept of masculinity by asking what predisposes a society toward a militaristic behavior. Regarding the interconnectedness of nuclear energy and nuclear weaponry, the support for the peaceful nuclear energy should be interlinked to the question of acceptance of nuclear war technology. One potential answer could be found in levels of gender equality within a society and a society's predisposition to militarism. According to a study by Hoy (1994) the relationship between gender inequality and militarism is – if it exists – very weak. However, the study also revealed that the authoritarian character, as defined and conceptualized by Adorno and colleagues (1950), is more likely to be hostile against outgroups and more willing to subordinate groups of society, such as women.

From my perspective the communicative relationship of an individual towards a risk is of importance. If someone is interested in understanding a risk, to understand how 'something' has the ability to change society, multiple perspectives are necessary to observe a risk's nature. Risks in this sense can only be understood if people understand the communication structures used in society to talk about and to define a risk. If risk solutions were to be based on the principles of equity, the existing gender gap should be closed to make sure that all parts in society, independent of their historically shaped presence or weight in institutions and decision making, have an equal voice to express their opinion (MacGregor, 2010; Olofsson et al., 2014). Gender balanced risk managing practices will probably lead to a more accurate understanding of risks.

5.3.3. The gender gap in cross-national comparison

In this section I will present two results from national and cross-national research to describe how risk perception, with a focus on the assumed gender gap, is perceived across different societies. In an Swedish study on risk perception, no 'white male effect'could be found (Olofsson and Rashid, 2011; Olofsson and Öhman, 2014). The authors hypothesize and conclude that social inequality creates different levels of risk perception within a society, and that in an egalitarian society such as in Sweden, no lower risk perception for dominating groups is produced. The authors suggest to call the white male effect more appropriately the "societal inequality effect" (Olofsson and Rashid, 2011, 1030). In the same sense, Slovic argues, when concluding that the observed gender gap is based on sociopolitical aspects such as power, alienation, trust, and status. From his perspective the problem of risk conflicts is "deeply rooted in the social and political fabric of our society" (Slovic, 1999, 693). He remarks that studies on experts, such as physical scientists (Barke et al., 1997) and toxicologists (Slovic et al., 1997) show that women express higher concerns of risks than their male colleagues. The results show that the gender gap remains, even when controlling for knowledge and occupational status, indicating that the roots of the observed differences are located deep in a societies consciousness.

The influence of knowledge on environmental risk perception or environmental concern is worth a cross-national comparison. A study by Shields and Zeng (2012), using 'The China Survey', reveals that on average women consider environmental problems as less serious than men. The differences in percentage points are not that big and in the multiple regression analysis the gender effect is not significant. What is of interest is that better educated people, people who are married and people who trust less in government officials tend to show higher concerns about the environment. The authors therefore conclude that the observed gender gap exists due to the women's discrimination in education and poverty. The trade off between economic progress in China and environmental degradation could be a reason why men perceive environmental problems as a serious threat for China's economic growth in the future. This complex interplay of environmental degradation and economic development for developing countries might be a reason for the reversed gender gap in China.

5.3.4. Age

Age is assumed to serve as sociodemographic predictor of environmental and technological risks concern in society. From a cultural theorist's point of view, older people are expected to have a more traditional worldview, tending towards a hierarchical bias. Furthermore, it is assumed that older people become less integrated into society, they therefore develop the views of a stratified individual or the biases of a fatalist worldview (Grendstad, 2000, 224). This assumption was empirically supported by Peters and Slovic (1996, 1438). Since more hierarchical biased people are assumed to show lower risk perception, it can be hypothesized that older people tend to express lower risk perception or environmental concern.

Van Liere and Dunlap (1980, 182–183) hypothesize a negative correlation between age and environmental concern. The theoretical explanation the authors provide is that younger people are less integrated into the existing dominant political, economic, and educational system (compare also Malkis and Grasmick, 1977). Since environmental and technological risks are a result of the existing dominant system, younger people should express higher support for environmentally friendly reforms and pro-environmental ideologies. Younger people are assumed to be more supportive of changes for more sustainable system. Older people who have built the system are more likely to express their opposition against progressive value changes, changes in communication and decision making. According to the socioemotional selectivity theory (Carstensen et al., 1999) it is also assumed that older people try to maintain harmony in their social group and, hence, orient themselves more according to existing social norms.

An additional approach to explain different responses of environmental risk perception among different age groups is based on the theory of generations by Karl Mannheim (1972). Mannheim asserts that historical events occurring during certain periods of life, such as in the period of being a young adulthood, are able to affect a generation throughout their entire lifetime. According to this generational approach, post-war cohorts involved in the civil right movement in the U.S. or the anti-nuclear war movements in Europe should be more sensitive to pro-environmental attitudes or ideological shifts. Van Liere and Dunlap argue that the recurring news of environmental problems in the past decades should have kept a higher awareness of environmental problems alive, resulting in an even higher environmental risk perception once the young adults move into adulthood (Van Liere and Dunlap, 1980, 183).

There is also a tradition in the scientific community of pursuing a more economic shaped approach resulting in a cost-benefit analysis. Research in that area on the effect of age on individual's risk perception is using measures that are quantifying individuals risk perception through measures such as willingness to pay (WTP) to reduce a risk or the measure such as the value of a statistical life (VSL). As Dockins and colleagues (2002, 337–338) summarize, WTP as well as the VSL estimates show the highest levels for people of age 40. There is consistency in the results that the effect declines as people get older. The estimates differ widely for younger people. For younger people, it is assumed that they worry more about potential risks compared to older generations (Cebulla, 2009, 52), especially for employment insecurity. Even though the globalized world with its complexity bears many opportunities for the young generation, it also increases the chances for potential losses and increases pressure on younger cohorts. This pressure could result in a resurrection of traditional values and in higher acceptance of technological risks to support a society's existing economic model. On the other hand, it has been argued that younger people face a longer life span or time-horizon than older people. Future oriented goals are more likely to be discussed and developed by younger individuals, therefore it can be assumed that the awareness of negative environmental consequences due to the existing economic and political system is higher among younger generations. As a result, higher risk awareness and awareness for environmentally responsible choices could be higher among young people with a longer time horizons (Wiernik et al., 2013, 828).

In a meta-analysis on the age effect on different environmental variables, such as environmental concern, values, attitudes, and environmental behavior, Wiernik et al. (2013, 844–845) conclude that in most cases individuals of different ages and generations did not show differences in their environmental attitudes and behavior. The authors observe that older people tend to rely more on traditional norms, such in the case of traditional work values, on conserving resources, and to avoid harm to the environment. For people in the workforce an age-difference are unlikely to be observed, the authors conclude.

The aging effect, expressed in value change towards more conservative values as individuals got older, was observed in a study of acceptance of a nuclear power plant (George and Southwell, 1986). The age effect was obvious for males with children, who were older and more likely to support the licensing of a new nuclear power plant. This effect was not observable among women with or without children. A generation explanation can be put forth. In the case of nuclear power older respondents were socialized to nuclear power in the early ages of that technology when nuclear power was perceived as a merit to social growth and a source of unlimited and cheap energy for the future. This early optimism is unlikely to be observed among younger generations, who faced different technological and economical crises during their socialization (George and Southwell, 1986, 732). This generational effect should be observable for both sexes, though the effect should be more obvious for the dominant male character as the creator of the technological age and its institutions than for women, who benefited from their husband's technological innovations and decisions.

Given the different explanations, the assumed negative effect of age should be assumed not to be clearly pronounced across all societies. Younger generations might see more opportunities in the future and show more willingness and openness for change. It may be possible to encourage younger people to be open to change existing social practices and institutions, in contrast to older people who are less willing to adopt changes and to rethink existing ideas. At the same time older people, being more experienced, will be more careful about their social environment and may be evaluating changes and individual actions more carefully (Morris and Venkatesh, 2000; Smola and Sutton, 2002).

5.3.5. Social status: education, income, and occupation

In the literature on environmental concern, it is assumed that environmental concern is positively related with social status or social class, identified by education, income, and occupational prestige (Van Liere and Dunlap, 1980, 183). The environment is perceived as a valuable good that will become an object of greater awareness, once an individual has satisfied all its basic material needs. Maslow's hierarchy of need theory (Maslow, 1970), the underlining theoretical model, holds that the most important basic material needs that need to be met are security and economic stability. The assumed positive relation between class and environmental concern has been questioned, arguing that poorer classes usually are more exposed to polluted areas as well as more dangerous work environment. This direct experience of poor environmental conditions should result in higher environmental risk awareness among members of the lower class or people having lower social status. Vaughan and Nordenstam (1991, 52) argue that previous research in the United States on risk perception does not support the assumed positive correlation between class and risk perception. Especially for risks, such as nuclear waste and toxic contamination, minorities express higher levels of concern, at the same time they are exposed to higher levels of social risks, such as unemployment and crime.

A French study by Bastide et al. (1989) showed that French respondents with higher education and higher income, living in urban areas, were more likely to underestimate the frequency of causes of death from various deceases and accidents. Respondents with lower socio-economic status, being unemployed or living in a town, on the contrary, were more likely to overestimate the frequency of causes of death. The authors explain the high levels of perceived risks among lower class respondents by assuming that an insecure social position will result in a feeling for greater hopelessness. The overall feeling of insecurity and loss of control eventually will cause higher levels of concern and will be expressed through an overestimation of risks, as the authors conclude (Boholm, 1998, 148–149).

In a Scandinavian and North-American comparison of environmental concern, higher educational levels were found to be consistently related to higher levels of environmental concern among respondents in all countries (Olofsson and Öhman, 2006). This result confirms prior assumptions about the positive relationship of environmental risk perception and education (see for instance Dietz et al., 1998). The effect of socio-economic status and environmental risk perception is assumed to vary according to the specific risks that are asked to be evaluated and judged. Broader environmental concerns, such as climate change, seem, as in the case of a study in Great Britain, not to be related to respondent's acceptance of nuclear power (Corner et al., 2011). I assume that nuclear power is seen as a source for economic growth and social stability. People with higher education, especially within the subgroup of men, tend to express lower levels of risk perception; yet at the same time, they express higher levels of environmental concern. Nuclear power from that perspective is not perceived as a threat to their health or to the society.

5.3.6. Political ideology

A consistent finding in scientific literature on nuclear risk perception is that more conservative or right wing oriented person express lower levels of nuclear risk perception (e.g, Eiser et al., 1990; Van Liere and Dunlap, 1980). The above discussed white male effect in the United States (Flynn et al., 1994; Finucane et al., 2000b) is an quite obvious example of how political ideology, in combination with socio-economic status, hierarchical, individualistic, and anti-egalitarian worldviews is shaping individual judgements of environmental and technological risks for society.

According to Dunlap (1975) environmental attitudes are able to be related to political ideologies, first, because environmental reforms in many cases have negative consequences for existing business and industry structures, due to higher costs and more regulation. Second, in many cases environmental reforms require social changes and new and innovative political and societal actions. Hence, the political ideology hypothesis according to Dunlap (cf. also, Van Liere and Dunlap, 1980, 185) can be summarized that political ideological cleavages leave a molding in individual's environmental risk perception. In the case of the United States, the cleavage is between Republican and Democrats, and more broadly speaking between more left liberal and more right-wing conservative individuals.

Dietz and colleagues also note that "political liberalism" serves as a very consistent ideological factor to predict environmental beliefs and pro-environmental action (Dietz et al., 1998, 464). It seems, as Finucane et al. (2000b, 170) conclude in their study on the white male effect in the United States that hazardous technologies and activities are perceived as a greater risk for people who put "more weight on distributing wealth equitability and endorsing community-based regulation" as well as put less weight on the "importance of individual achievement," social values that are closely related to political liberalism. The value gap and the predominant left-right distinction, not only in the United States, can be found in many areas of life. Liberal, left wing ideologies on the political identity scale are associated with the ideas or social domains of progress, quality, feminism, and other vague concepts such as flexibility, chaos, and rebelliousness. Conservative right wing ideologies are associated with hierarchy, order, stability, tradition, and conformity (Jost et al., 2008, 126).

As Kahan and colleagues (2007) argue a specific subgroup will try to protect their individual and their sub-group specific identity, based on a strong commitment to predefined cultural norms. It is important to understand that a more conservative ideology, committed to maintaining the existing order, is based on an emotional process combined with social activities. Any outside attempt to challenge or question the existing order, and with that the emotional foundations and its expressed social activities, will, result in system justification tendencies. This effect will be stronger for people who place themselves on the right hand side of the political ideology scale, compared to people on the left hand side of the scale (Jost et al., 2008). In line with Feygina et al. (2010), McCright and Dunlap (2011, 1165) argue that beside the system justification tendency also the tendency to denial environmental as well as technological problems, such as climate change or nuclear power is higher among more conservative people. Denying problems is one means of protecting one's own identity.

Kahan et al. (2007) furthermore argue that people form their beliefs according to their cultural worldviews and since they are grouping themselves in different societal subgroups, these beliefs are reinforced within the specific subgroups. Since there are social dynamics within these groups that are reinforcing the existing believe structures, outside or new informations are rarely received without filter strategies that translate the new information into the jargon of the existing believe system. The new information will either be accepted and integrated or resisted. Beside these theoretical approaches based on worldviews and group cognition theory, McCright and Dunlap (2011, 1165) argue that political and industrial power is an important motivation for the subgroup of the white male to not change the existing believe structure. With the example of the tendency to deny climate change among conservative white males, the authors refer to the media power the conservative political elites and oil industry use to constantly repeat the message that fits best to maintain their identity and power. McCright and Dunlap (2011, 1165) point out that conservative white males will continue to denial climate change "to defend the information disseminated within their in-group and to protect their cultural identity;" they also will put effort to protect their economic status as the elite and "are likely to favor protection of the current industrial capitalist order which has historically served them well." The hegemonic masculinity, I want to argue, has created the ideological cleavages and the accumulation of power, implemented through social institutions, based on inequality and discrimination. For me the most striking evidence that the dominant system is trying to denial any changes can be found on the acceptance of discrimination and inequality.[52]

5.3.7. Urban, rural, and regional differences

In their residence hypothesis Van Liere and Dunlap (1980, 184–185) state that urban residents should be more likely to express higher concerns about the environment than rural residents. The authors put forth three possible explanations. First, it is assumed that urban residents are more likely to be exposed to environmental problems that

[52] For instance, Finucane et al. (2000b, 166) show that 40.1 % of the subgroup of white male disagree with the statement "that the world needs more equal distribution of wealth." In contrast to that proportion among the rest of the population only (or still) 23.3 % disagree with that statement, a much lower proportion.

affect their health such as air pollution, noise or toxic contamination and, hence, should express higher levels of concern. The exposure to bad environmental conditions is the cause for higher levels of concern. A second explanation is based on the assumption that different occupations lead to different attitudes towards the environment. It is assumed that rural residents are more involved in nature-extractive occupations that uses the environment as a resource, such as farming, lumbering, or mining. Rural residents therefore developed an utilitarian attitude towards the environment and are less aware to perceive the environment as part of their lives that needs to be protected. A third explanation, related to the economic growth explanation, assumes that the size of a town correlates positively with environmental concern because small towns are competing with larger human settlements and extract their resources to maintain economic growth as a way to survive (Freudenburg, 1991).

An additional explanation can be put forth arguing that socio-economic status in rural environments influences environmental risk perception. Bastide et al. (1989, 218) could show in their French study on risk perception that farmers living in villages were more optimistic or less concerned about the consequences of risks when rating risks and its mortality rates. The farmers' optimistic views showed many similarities to people who lived in the city or were better educated and had more income. An U.S. study by Freudenburg (1991) on the contrary, could not find lower levels of environmental concern among farmers and rangers compared to residents in the same communities. People working in the agricultural sector were even more likely to express higher levels of concern compared to people with other occupations. His results support the economic growth and the nature-extractive explanation because the lowest levels of concern could be identified among coal mining and growth-related business occupations. Socio-economic changes in rural communities, such as growing population rates and new employment opportunities, are also changing resident's risk perception. In a comparison of different rural communities across the United States, Hamilton and colleagues (2013) showed that in areas with high growing populations and occupations that were not resource-based, residents were more likely to accept environmental rules that were more likely to restrict economic development.

The relationship between of place of living and environmental attitudes seems to matter but the empirical results do not indicate that there is one dominant relationship (c.f. for instance Olofsson and Öhman, 2006) and, hence, no clear explanation can be identified. The relationship varies between places and between risks (Freudenburg, 1991). Attitudes are associated with socio-economic factors such as the occupational sector that is dominant in a specific area. The effect of place on environmental risk concern should be used with caution when used as explanatory factor because socio-economic factors such as education, income, or gender seem to have comparably more explanatory power (Dietz et al., 1998).

The effect of place or region should also be reflected from a broader historically and politically perspective. Environmental topics are highly emotional, of symbolic value and can be used by decision makers to gain support for their own political ideology or to oppose existing political power structures, even if there are no economic or deeper social interests involved (Freudenburg, 1991, 194). The nuclear energy issue, a topic of high symbolic value, also serves as a political topic to oppose political decision from state authorities for separatists movements in European countries, such as in the French region of the Brittany, in the Spanish Catalonia and Basque region, or in the United Kingdom in Wales and Scotland (Kurlansky, 1981). This seems to be the case, especially in countries that are politically highly centralized, such as France, and countries that still have historically grown political conflicts between the central government and cultural minorities, having the majority in one specific part of the country. As Kurlansky states, the anti-nuclear movements in that areas are a mixed group of environmentalists and separatists, creating a security problem for the technology within a government's national territory.

5.4. Cross-national differences in (nuclear) risk perception

This section addresses questions about the comparison of cross-national and cross-cultural approaches to explain risk perception. The overall question is whether there is a universal explanation of risk perception such as the psychometric paradigm approach (compare Section 4.2.2) or whether risk perception varies highly due to cultural differences, the anthropologist's approach. In the later case, it is assumed that the social fabric in which humans are embedded are shaping individual's risk perception: the equity structure, values of justice and religious ideologies, the concepts of property and sovereignty, the value of nature (Rappaport, 1996, 160).

Boholm (1998, 160) in her overview on cross-national risk perception studies, states that comparative studies should aim to improve the theory to explain the observed results and should contribute to get a deeper understanding of the underlying principles that may vary across cultural boundaries or are quite similar across different cultures. It is also important to compare the underlying structure, if possible, that forms individual's risk perception in different cultures. For instance, in the case of a comparison of nuclear risk perception in Japan and the United States (Rosa et al., 2000), different mechanisms forming risk perception in both countries seem to lead to the same observed levels of risk perception. Blind empiricism for the sake to produce observable differences, without reflecting the possible explanatory factors, will not be helpful to reveal the difficult to access areas of human's risk perception, especially in a cross-national comparison (Faucheux, 1976).

In a cross-national comparison between the United States and Japan, Rosa et al. (2000) tested whether risks, measured with the psychometric paradigm, are perceived differently between two different cultures (c.f. also Kleinhesselink and Rosa, 1991). Both countries are on a high industrialized level, however the historical development and cultural heritage of both nations is different. Analyzing nuclear risk perception, the authors tested the cognitive structures that eventually result in images of a risk's catastrophic and dread potential. Even though the risk perception was quite similar between both cultures, the underlying processes turned out to be fundamentally different. According to the author's model, Japanese respondents create their catastrophic images as a function of both lack of individual knowledge and perceived little control over risks. The American respondents seem to perceive catastrophic risk images as a function of lack of scientific knowledge about a risk and perceived little control (Rosa et al., 2000, 206).

Regarding the cross-cultural validity of the psychometric paradigm Boholm (1998, 143) concludes in her comparison of cross-national studies (e.g, Lichtenstein et al., 1978; Goszczynska et al., 1991; Karpowicz-Lazreg and Mullet, 1993) that, even if differences in factor scores appeared, the main factors were related to dread potential and knowledge. Hence, the cognitive structure of risk perception, as measured by the psychometric scale, can be assumed to be quite similar across different national and cultural boarders.[53] Nevertheless, to claim that the psychometric approach is able to explain all possible risks in the future seems to go to far: "However, the conclusion that the cognitive structuring of risk should be regarded as universal seems to reach too far, since it is hardly likely that the psychometric scales adopted by reasons of their use in earlier studies, would exhaust all possible meanings of risks" (Boholm, 1998, 143).

A comparison of nuclear risk perception between the United States and France revealed that respondents in both countries express similar levels of concern about nuclear energy's hazardous nature (Slovic et al., 2000a). In both countries, nuclear waste and nuclear energy were perceived as very high risks for safety, health, and environmental quality. The same levels of risk perception indicate, as the authors remark, that risk perception cannot explain the different levels of acceptance or reliance on nuclear energy that exist in both societies (Renn and Rohrmann, 2000b, 215). This result is surprising because in France nuclear energy is still widely accepted by the major parties and public institutions. A clear difference between both countries was found in public's trust-relationships towards scientific expertise, industry, governmental institutions, and policy-makers. In France, respondents trusted that the public elites have the best expertise to make the necessary decision about nuclear power. Respondents in the U.S. showed lower levels of trust in public elites and expected that citizens should be involved in the decision making process regarding all nuclear issues (c.f., also Karpowicz-Lazreg and Mullet, 1993). These historically grown differences in political culture explain the observable differences in nuclear risk culture in both countries, the authors conclude. In the United States, people want to be involved in the decision making process, not trusting public authorities to act in the best possible way or in public interest. In France the political culture is based on trust in the elite-structure, assuming that the best available experts will be consulted and that the bureaucratic structure will actually create the optimal solution. For French respondents, nuclear energy is also more likely to be perceived as a technology of national interest fostering economic growth and social well being (Renn and Rohrmann, 2000b, 216).

[53] It should be taken into consideration that the sampling process of countries is a non random process. A generalization on a global scale is problematic.

Similar to previous research on risk perception in France and the United States (c.f., Karpowicz-Lazreg and Mullet, 1993), women in both countries were more concerned about nuclear power than men. The sub-group of white males in both countries was more likely to support nuclear power and expressed lower levels of risk perception. White males in both countries tend to have higher income and were better educated, were more likely to believed in authoritarian and anti-egalitarian worldviews, and regard risk taking behavior, technological and scientific progress as source for economic growth and wealth (Renn and Rohrmann, 2000b, 216). Comparing additional sociodemographic factors, beside gender, in the U.S. as well as in the French sample (Slovic et al., 2000a, 82–85), no clear age differences were detected. In both samples people with lower education expressed higher concerns about future consequences especially the immoral heritage of nuclear waste for future generations. In both countries, respondents with college education or higher education levels were more likely to perceive nuclear as controllable and well understood by scientists and were more likely to perceive nuclear as an acceptable risk.

Testing cultural prototypes as explanatory factor for risk perception, Slovic et al. (2000a) could not separate and identify different groups, suggesting to regard worldviews as an ideal type of value orientation that individuals use to judge risks. What could be observed was that respondents expressing more egalitarian worldview tended to be anti-nuclear, whereas more pro-nuclear attitudes were expressed by people holding more individualistic and more hierarchical worldviews.

In a cross-national comparison of the psychometric approach, Goszczynska, Tyszka, and Slovic (1991) tested whether the basic factor structure can be observed across respondents in the United States, Poland, Hungary, and Norway. There was similar agreement on the two factor structure dread potential and familiarity, across all respondents, especially in Poland and in the United States. Hungarian respondents, on average, expressed the lowest risk concerns. The authors hypothesize, that a country's size and its media coverage of risk events could be an influential factor that shapes individual's available information on risks. The Polish sample ranked warfare and nuclear weapons among the most dreadful risks. Nuclear energy was perceived as highly unknown but ranked as a quite moderate threat risk. Economic and social risks, such as economic crisis or social tensions, were perceived as more of a threat than the technological risk of nuclear energy (Goszczynska et al., 1991, 190–191).

In a cross-national comparison of samples from Australia, Germany, and New Zealand, Rohrmann (1994, 160) concludes that cross-national differences in risk perception are rather small. In all countries, psychological factors, such as dread potential or familiarity, seem to play a more important role in judging risks than objective criteria such as mortality rates or cost/benefit calculations. Furthermore, individual's cultural orientations turned out to be a source to identify differences in risk perception. What Rohrmann (1994, 152) defines as 'technological' orientation seems to influence risk perception negatively. People with a more 'ecological,' or 'feminist' orientation expressed highest levels of risk concern. However, what seems to matter more than cross-national differences are differences between ideological or societal subgroups within a country. For instance, in Germany the polarization is higher compared to the polarization in Australia for the acceptability of technological risks such as chemical industry or nuclear power.

Given the broad spectrum of a society's explanatory factors on risk perception, and given the possible interplay of factors within the social fabric, it is of no surprise that in her comparison of cross-national research on risk perception Boholm (1998, 160) suggests a more detailed investigation, using quantitative as well as qualitative methods, of the social "background factors," such as gender or socio-economic status, and the "ideological" factors, such as political orientation. The role of the political power structure and the underlying trust relationships among elite subgroups, as well as marginalized groups, seem to reproduce ideological cleavages that are reproducing the order of hierarchy and authority.

Since risks are socially constructed, risk perception approaches that consider both views, i.e. the value based cultural and the socio-economic based view, as I conclude, could be an indicator to detect the prevalent power structure among social entities and its sub-cultures. The role of national and international media as information source and amplification stations for changes in risk perception and with that the language how risks are communicated[54] is also a factor, not to neglect in risk perception research in cross-national comparison.

5.5. The accident effect on nuclear risk perception

In the following part, I will continue to provide an overview of previous studies on risk perception in either one country or in a cross-national comparison. This part will also focus on studies that specifically examine the effect of an nuclear accident on people's nuclear risk perception, such as the accidents in Fukushima (2011, Japan), Chernobyl (1986, Ukraine), or Three Mile Island (1979, USA). This overview will by far not be comprehensive, given the broad range of studies on environmental and technological risk perception since the 1970s. The aim in this part of the dissertation is to learn more about the extent and the interplay of the above mentioned social background factors and underlying ideological factors, in order to get a deeper understanding of the social structures that shape nuclear risk perception. It is furthermore important for my work to understand the effect of a sudden event like a nuclear accident on individual's risk perception. This overview is quiet selective and done by snowballing a reference through the available scientific databases, such as 'Cross Ref' or 'pro quest' using the keyword search function to search in selected scientific journals for keywords such as 'risk perception' and 'Fukushima.'[55]

[54] Compare for instance for a cross-national comparison of risk communication in the United States and Germany (Dunwoody and Peters, 1992).

[55] Boholm (1998, 137) is reporting a similar strategy for her overview on risk perception research.

A study that quite clearly shows the different individual and social factors that form nuclear risk perception and attitudes toward nuclear power is Withfield's et al. (2009) article 'The Future of Nuclear Power: Value Orientation and Risk Perception.' The authors use an adapted values-beliefs-norms (VBN) model to examine the combined direct and indirect effects of human values and social context variables that form, from their point of view, attitudes towards nuclear power. The dependent variable is the acceptance of nuclear power. Nuclear risk perception in this model is one explanatory factor of risk acceptance. The authors use a structural equation modeling (SEM) to test the VBN model. According to the SEM analysis, values such as traditional or altruist value orientation influence attitudes toward nuclear power indirectly through trust in political and nuclear organizations. People, holding more traditional beliefs expressed greater support, whereas more altruist people expressed higher levels of opposition to nuclear power. Individual demographic factors such as political orientation, age, race, and gender only indirectly through their value orientation have an effect on nuclear risk perception and, hence, the support or opposition of nuclear power. Education turned out to be the only demographic factor that directly influenced individual's risk perception on nuclear power. People with lower education expressed higher perceived risks.

According to Withfield and colleague's work, trust in the managing institutions and the perceived risk of nuclear power are the main direct influencing factors that define whether people are in favor or against nuclear power. Values indirectly and directly also influence attitudes towards nuclear power (Whitfield et al., 2009, 433). Given the interplay of demographic factors, trust in institutions, and value orientation, the authors conclude that individuals cannot be blamed for being too rational or too irrational when forming their attitudes and expressing their judgements about nuclear power: "It shows that the individual decisionmaker is neither an isolated, cold, calculating maximizer of the rational actor paradigm, nor is the "cognitive cripple" ruled by incoherent thinking once believed in the psychology of risk. Instead, the decisionmaker exhibits a rich combination of cognitive insight, social and emotional intelligence, and cultural awareness, all anchored by fundamental values showing concern for others and the environment" (Whitfield et al., 2009, 433).

Nuclear attitudes are deeply routed in the value system and not easily changed or modified by communication strategies, that tries to convince the public of risks and benefits of technology (c.f. Eiser et al., 1990, 110). The strong reliance on values helps individuals to select the relevant information behind competing sources of information. It simplifies the process of testing and assessing the evidence of competing views. The idea of Bayesian updating (c.f. for example Bassett and Jenkins-Smith, 1992) explains why depending on the initial strength of individual's a-priori beliefs, new information changes these prior beliefs to a varying degree: "In essence, we are suggesting that members of the public are informal Bayesians, so that their values and general beliefs are strong priors, and information presented in the media or in survey instruments are given limited weight in updating assessments" (Whitfield et al., 2009, 427: footnote 8). I will refer to perceive the public as "informal Bayesians" in Section 7, examining the immediate effect of the Fukushima accident on nuclear risk perception.

The authors put forth the argument that the public's attitudes towards nuclear technology in the United States are historically grown and closely linked to the anti-governmental and anti-nuclear protests in the 1970s. This argument underlines the importance of values that influence nuclear attitudes. Social movements expressed not only concerns about the thread of nuclear technology and nuclear war, but against a highly centralized state and a militarily organized security system that would be needed in order to manage and control nuclear power. The anti-nuclear movement, was a movement against an elite system based on the foundations of military and industrial progress, and technoscientific reasoning – or as the authors express: a "technoscientific-industrial-military elite" (Whitfield et al., 2009, 434).

In the United States, as well as in Japan the historical context seems to matter. In both countries nuclear technology is perceived as a risk because of its combined and unknown consequences such as the fear of an accident as well the fear of nuclear war (Hinman et al., 1993). In the case of Japan, contrary to the U.S., nuclear risks are perceived as known rather than unknown. It is assumed that in the case of Japan the historical experience of bombing Hiroshima and Nagasaki in August 1945 is explaining the knowledge about nuclear risks rather than cultural differences between these tow industrialized countries (Kleinhesselink and Rosa, 1991).

In a UK based study using data from the Eurobarometer 2005, Costa-Font and colleagues (2008) argue similarly to Whitfield et al. (2009) that attitudes toward nuclear power depend to a great extend on individual's political orientation and trust in managing institutions. The authors argue that nuclear is a politically sensitive issue and by judging nuclear risks people activate basic values that are held and expressed by their party affiliation: "[t]he party affiliation then becomes their anchor from which to evaluate risks" (Costa-Font et al., 2008, 1274). Due to limited knowledge, experience, and information it is assumed that people use their party affiliation as an anchor heuristic (compare Tversky and Kahneman, 1974) to evaluate the risk of nuclear power. Results show that more knowledgeable people express lower acceptance of nuclear power (Costa-Font et al., 2008, 1284). These results question the assumption that more knowledge and better information about nuclear technology will reduce individual's risk perception. These results support the above mentioned doubts about the 'Knowledge Support Hypothesis' (compare Section 5.3.1) and adds more evidence to what Sheldon Ungar calls the "knowledge–ignorance paradox" (Ungar, 2000). Knowledge only is one factor of many in the interplay of values and available information that forms nuclear attitudes. The complex interplay of values, demographic factors, trust in institutions, and available information does not allow for the assumption that there "exists any single or stable public 'opinion' on such complex matters" (Pidgeon et al., 2008, 69).

Pidgeon and colleagues, in a study in the United Kingdom in 2005, analyzed public attitudes towards nuclear power and climate change. In the case of two highly controversial risks, such as climate change and nuclear power, public opinion about the combined risks is not a simple risk-risk tradeoff (i.e. that people would prefer one risk over an other, such as the conclusion, to prevent climate change, people are willing to accept more and clean nuclear energy) but a value driven evaluation that seeks for new and more sustainable solution in the future, such as new strategies for renewable energies (Pidgeon et al., 2008, 81). Historically in the UK, the public has expressed constant concerns about nuclear energy, especially after the accidents of Three Mile Island and Chernobyl and still remains skeptical about its use in contributing as a energy source to tackle the unexpected consequences of climate change (Corner et al., 2011). Corner and colleagues (2011, 4830) emphasize the concept of "reluctant acceptance", perceiving nuclear energy (see also Bickerstaff et al., 2008) as a necessary evil to swallow. It turned out that environmental values negatively influenced public's support for nuclear energy even, if nuclear was framed as a solution to climate change and energy security issues. The influence of pro-environmental values by activating heuristics to evaluate nuclear energy indicated that people still perceive nuclear as an uncertain and insecure technology. The authors assume that when confronted with a judgement about nuclear energy, people in the UK seem to feel tension between their analytic and affective reasoning. Only when people were able to express their concerns about nuclear power, when being a reluctant supporter, did increase the chances to support nuclear power as a means against global climate change (Corner et al., 2011, 4831).

The paper by Corner et al. was written right before the nuclear accident in Fukushima. In a postscript the authors are mentioning the accident (Corner et al., 2011, 4831). From their point of view, the nuclear accident in Fukushima is comparable with the nuclear accident of Chernobyl regarding the damage of the power plant, radiation released, and the loss of safety systems. From the authors' point of view, it is unclear what long-term impacts the accident has on nuclear attitudes. Most of all, the accident reveals the "social resilience" (Corner et al., 2011, 4831) among the public. As nuclear is perceived as a dreadful and unfamiliar technology, even feelings and attitudes of familiarity and acceptance are not forearmed to be overrun by latent anxieties and concerns people still hold (Parkhill et al., 2010). Policymakers, if trying to promote nuclear as an environmentally friendly technology, should therefore keep in mind, when deciding future's energy strategies, the fatal consequences of unwanted negative events that are able to happen at close or distant placed at any time.

In the following part I now want to more closely examine the consequences of a major nuclear accident, such as in Fukushima and Chernobyl, on nuclear risk perception in selected countries. I will start with analyses that examined the effect of Chernobyl. In a study of a local British community, located near a nuclear power plant, Eiser et al. (1989) compare attitudes towards nuclear power before and after Chernobyl. The authors expected that the accident would increase anti-nuclear attitudes. This overall effect of the accident is assumed to be diminished by several cognitive strategies to resolve a possible dilemma because of the new incident (c.f., Abelson, 1959). Eiser et al. (1989, 690) mention four strategies: 1) differentiation, i.e for example that British nuclear power can be trusted but not Soviet one, 2) denial, i.e. for example that people refuse to accept the scale of the accident, 3) bolstering, i.e. for example emphasis on the benefits of nuclear technology, and 4) transcendence, i.e. for example the accident was an unwanted event that helps to improve and to learn more about the technology. Depending on the selection and the combination of available coping strategies the assumed negative effect of a nuclear accident should be less pronounced. As a second theoretical explanation, the authors mention the "accentuation theory" (Eiser and van der Pligt, 1982, 226). According to this approach, respondents will rate evaluations of risks according to their a-priori acceptance of a risk leading to a polarization among members of a community after an accident. People holding anti-nuclear attitudes will perceive anti-nuclear ratings as either too rational or as an alarming trend of ignorance in the community leading to an increase in risk perception. People holding pro-nuclear attitudes prior to the accident on the other hand will perceive anti-nuclear statements as too concerned and hysteric, leading to an decrease in nuclear risk perception or acceptance (Eiser et al., 1989, 691). The reported results of the before and after comparison of nuclear attitudes show that there was a shift towards more nuclear concern among respondents. Women were more concerned before and after the accident. It also turned out that respondents holding more pro-nuclear judgements paid less attention to and were less frightened by the news reported in the media about Chernobyl. The accentuation effect and, hence, the polarization was more clearly observable by pro-nuclear respondents. The authors also state that the absolute changes of nuclear attitudes were not large, given the large media reports on the Chernobyl accident. Therefore, the "absolute size of this effect should not be exaggerated" (Eiser et al., 1989, 699). According to the author's conclusion, a-priori attitudes towards nuclear energy act as mediator and attenuate or amplify new information. It is also the case that the rarity of an event of an accident is perceived as an isolated event or as an event that is part of a more general danger.

A nuclear accident should change or rises conflicts in people's belief structure due to at least two possible reasons. The first reason, as explained above, is an update of the actual probability or consequences of an unlikely event, revealing that previous estimates have been too optimistic. A Dutch study by Verplanken (1989) supports this argument, reporting an increase in the assumed probability of a nuclear accident in The Netherlands. The second concern people may express is society's vulnerability and the perceived options individual's have to reduce that vulnerability in the future (Eiser et al., 1990).

Renn (1990) analyzed changes in public attitudes towards nuclear power in Western-European countries after the Chernobyl accident. Regarding the formation of attitudes after the nuclear accidents he assumes an "inoculation effect" (Renn, 1990, 156). The inoculation effect states that people holding a-priori positive attitudes will be immunized against a negative event or the negative information of an accident. People feeling uncommitted, expressing a-priori a 'don't know' answer, will be more likely to perceive an incident as an opportunity to make a decision towards more skeptical attitudes of nuclear power. According to the theory of cognitive dissonance (Festinger, 1957), people with strong attitudes will try to avoid cognitive dissonance due to new information by ignoring or downplaying unwanted information. This strategy holds best for minor negative information of nuclear incidents. The initial shock of the new information will soon be outbalanced by the cognitive heuristics that serves to regain the predominant attitude.

In case of a major accident simple heuristics to form attitudes do not work anymore (Renn, 1990, 157). In such a case, cues serves as orientation to form an opinion. As cues serves the opinion of a strong reference group as well as trust in institutions. Renn assumes that immediately after an accident all available cues provide negative information. Interest groups and other organization will then form new positive laden cues to provide new evidence so as to overcome the accident's initial shock. The pre-accident levels of public's attitudes can be regained through assurance from trusted public institutions about a community's or country's safety. According to this concept, a constant change of attitudes will occur if ongoing negative information constantly questions the positive counter-evidence provided by social groups.

Renn (1990, 159) founds support for his inoculation concept by comparing opinion polls of the acceptance of nuclear power before and after the Chernobyl accident in Europe. Countries, such as France, Spain, and the United Kingdom, prior to the accident showed highly structured, i.e. committed and clearly defined, nuclear attitudes and were not much affected by direct contamination from the fallout. In these countries, the sudden shock of the accident did not raise public concerns much, and within a year attitudes towards nuclear power leveled back to pre-accident levels. Renn concluded, that because of strong a-prior support of nuclear power in these countries, a permanent shift in risk perception was not observed. Countries with highly structured attitudes prior to the accident that were more directly affected by the fallout in Chernobyl, such as The Netherlands, Sweden, Finland, Austria, West Germany, and Switzerland, did react more dramatically after the accident. Still, the initial shock of the accident diminished more or less after a year and pro-nuclear attitudes recovered. Greece is an example of an attitude shift towards more concerns about nuclear power, that did not recover to pre-Chernobyl levels. Greece was not affected much by the fallout but many people expressed uncommitted or undecided positions a-priori to the accident. Therefore, Renn concludes that attitude changes will only occur in countries, or communities, that are directly affected by the negative consequences or that a-priori hold a strong proportion of indecisive or indifferent opinions about the risk, an indicator for ambivalent feelings and opinions. These findings are supported by a longitudinal study in The Netherlands (Midden and Verplanken, 1990). The authors show that supporters of nuclear power on average held less stable attitudes compared to opponents. It turned out that supporters expressed more ambivalent tendencies in judging nuclear risks and benefits compared to opponents.

The Swedish population was directly affected by Chernobyl's nuclear fallout. People changed their attitudes because of a change in risk perception and because of the perceived effects of the accident (Drottz-Sjöberg and Sjöberg, 1990, 146). The shock was counterbalanced to pre-Chernobyl levels by authorities trying to communicate pro-nuclear attitudes that on the one hand emphasized the relevance of nuclear power for national's economy, and on the other by expressed trust in the national power industry and its capability to prevent nuclear accidents. There was one group of people whose attitudes were much more affected by the accident resulting in higher and long lasting anti-nuclear attitudes: farmers, as well as women, and people who lived in the Gävle area, the area that was the most exposed to nuclear radiation, expressed much higher levels of concerns after the accident. The authors of the Swedish study conclude that: "subgroups of our sample who reported high levels of worry and of perceived risks, apart from subjects in the specifically exposed region, fit nicely into a category of subjects more related than others to food production, human reproduction and care" (Drottz-Sjöberg and Sjöberg, 1990, 147). The feeling of responsibility for lives of others and future generations, the idea of care taking, not only for one's own future but for the whole social entity might be one main factor that is triggered when you or your community is exposed to the immediate and future consequences of a nuclear accident. Men in the most affected area Gävle show higher levels of risk perception compared to men in the rest of the country. It seems that the actual stress of the accident combined with forced changes in daily routines, such as changes in eating habits and outside activities, affects long term nuclear risk perception.

A study in West Germany, which was also directly affected by the nuclear fallout, notes the "massive disruption in people's daily life" for everyday routines, most obviously the change in peoples's diet (Peters et al., 1990, 132). The available information and its inherent inconsistencies, contradictions, and uncertainty after the accident fostered people's orientation towards intuitive and emotional judgements, forming a subjective measure of the given uncertainty. Trust in institutions eroded right after the accident, indicating that there was no accepted authority in West Germany able to provide enough information to maintain trust and credibility. The long term consequences of the Chernobyl accident in Germany are reported as being split. On one hand, the uncertainty about the health threat was not relieved even two years after the accident. What changed was the alarming public debate about Western Germany's energy needs in the future. This debate lost its intensity over time. The authors wonder why the political opposition against nuclear power did not show higher levels and did not last longer. The authors conclude that nuclear accidents are perceived as, what Charles Perrow calls, 'normal accidents' (Perrow, 1999) resulting in, what I would call an agony of modernity, or "the price one has to pay for the highly industrialized society and the consumer-oriented lifestyle" (Peters et al., 1990, 133). Earle and Cvetkovich (1990) criticized the use of the term of a 'normal accident.' The authors explain, in a response to the Peters' et al. paper, that Perrow's idea of a normal accident, is that normal accidents are not event that occur outside but an inherent part of systems that are tightly coupled and complex in terms of their interactions. They are a result of complex technologies and, hence, 'normal' or unavoidable. Chernobyl is an example of an accident of a coupled and complex system.

A study by Lindell and Perry (1990) reveals, when comparing attitudes towards nuclear power in the U.S. before and after Chernobyl, that the expected likelihood of a nuclear accident did not change significantly. The authors conclude that the experience of the Chernobyl accident did not lead to a polarization among respondents, rather to a convergence revealing that people's risk perception can decrease by learning that even an major accident has not the a-priori expected catastrophic potential. This study does not support the assumption of changes in attitudes after a nuclear accident. The accident did not change people's judgement of an accident's likelihood and people's vulnerability did not increase because the accident did not show the a-priori expected fatal consequences.

The Fukushima accident in Japan in 2011, unfortunately, offers the unexpected opportunity for social scientists to test changes in nuclear attitudes due to a major nuclear accident. It can be shown that the nuclear accident changed nuclear acceptance (Siegrist and Visschers, 2013; Visschers and Siegrist, 2013; Kim et al., 2013). Often the focus of studies is to explain how risk perception negatively affects acceptance of nuclear technology (Hartmann et al., 2013; Stoutenborough et al., 2013). The nuclear benefits are not part of the research question. In a Swiss study Visschers and Siegrist (2013) compare changes in risk perception before and after the nuclear accident. The authors use a longitudinal panel design of two waves to test how social trust in nuclear regulation agencies, perceived benefits, and perceived risks of nuclear power influence nuclear acceptance. Before the Fukushima accident, acceptance of nuclear energy in Switzerland was influenced to the most part by the perceived benefits and to a smaller degree negatively influenced by respondent's risk perception. Trust had a negative influence on perceived risks and a strong positive influence on perceived benefits. The panel design revealed that trust in 2010 (first wave before the accident) was strongly correlated with trust in 2011 (second wave after the accident). The model after the accident showed the same functional relationship as before the accident. After the accident, respondents reported higher levels of risk perception and lower levels of perceived benefits and trust, resulting in an overall lower acceptance of nuclear energy in Switzerland. The direction of the determinants of nuclear acceptance among the public did not change over time. In the observed time period, the most obvious change and the most influential determinant was not change in risk perception, but change in the perceived benefits. The authors put forth two explanations for this effect (Visschers and Siegrist, 2013, 343). Prior to the accident people already acknowledge the potential fatal consequences of a nuclear accident and the actual incident is only a confirmation of previously derived expectations. A closer look at respondent's potential benefit structure opens the space for an alternative explanation. Previous studies on nuclear acceptance did show that opponents of nuclear energy mostly held strong negative images of nuclear power, whereas proponents hold both, positive as well as negative images of nuclear power (Midden and Verplanken, 1990; Peters and Slovic, 1996). Hence, it is quite unlikely that people who perceiv nuclear power as beneficial a-priori to an accident are free of doubts about the technology. A nuclear accident, such as the Fukushima accident, is able to increase the negatively laden images of nuclear power among proponents, but does not affect, to the same degree, the already negatively laden image structure of opponents. The authors conclude that "the impact of perceived risks had not changed much after the Fukushima accident and that perceived benefits remained the strongest predictor of acceptance" (Visschers and Siegrist, 2013, 343). The authors also emphasize trust as an important factor that is able to change people's attitudes towards technologies (cf., Nakayachi, 2015). Trust remains an important factor that indirectly through risk perception and perceived benefits influences acceptance of nuclear power.

Quite similarly, a more recent Swiss study examined the mid-term effect of the Fukushima accident in two waves, one conducted 15 months before the accident and 20 months after the accident. Siegrist et al. (2014) examined explanatory factors behind why Swiss people changed from proponents of nuclear power to opponents or became undecided. Similarly to the above mentioned studies (cf., Visschers and Siegrist, 2013; Siegrist and Visschers, 2013) people with a-priori high benefit perception were less likely to change their acceptance of nuclear power. People with lower benefit perception, were more likely to become opponents of nuclear power or undecided. Perceived risks of nuclear power did not significantly influence changes in acceptance. The authors also controlled for gender and age as explanatory sociodemographic factors. In the regression analysis, age turned out to negatively influence acceptance of nuclear power. Older people showed lower acceptance of nuclear power after the accident, and older people who a-priori accepted nuclear power in Switzerland were more likely to oppose nuclear power after the accident. The authors concluded that the accident of Fukushima did not change people's risk perception, but rose doubts about the economic and environmental benefits of nuclear power for future needs (Siegrist et al., 2014, 361). The geographical distance of the accident is also a possible factor why changes in nuclear attitudes among the public can mostly be explained by changes in the benefit perception of nuclear power.

The geographical distance could also be a possible explanation for why, in a comparison of nuclear risk acceptance before and after the accident of Fukushima (Poortinga et al., 2013) in Great Britain and Japan, the population in Great Britain still held strong acceptance levels even after the accident. People in Great Britain, for instance, still supported governmental strategies to increase nuclear power production in the future. According to the authors, Japanese respondents changed their attitudes "dramatically" (Poortinga et al., 2013, 1210). The changes in acceptance of nuclear power were influenced to a great extend by low trust levels in Japanese's safety regulation agencies. The authors conclude that in Great Britain the benefit structure of nuclear power did not change after the accident, whereas in Japan it declined. In Japan, the results indicate that compared to pre-Fukushima levels, at least in the short run, nuclear power was less accepted as a mean for energy security and climate change mitigation.

The direct effect of the Fukushima disaster on environmental concern in Germany was examined in a paper by Goebel et al. (2015). The authors use a Difference-in-Discontinuity model to identify the causal effect of the accident, comparing respondent's attitudes before and after March 11, 2011. In Germany there was an immediate increase in environmental concern[56] and an immediate decrease after the German conservative

[56] Environmental concern was measured by the question: "What is your attitude towards environmental

government announced the 'Nuclear Phase-Out Bill' (Atomausstieg) on May 30, 2011. Female respondents showed the strongest effects in changing their attitudes. Supporters of the German Green party did not change their attitudes much after the accident, indicating that supporters of the Green party already had a-priori high environmental concerns. Green party supporter expressed higher reliefs once the Nuclear Phase-out Bill was passed. In this case, a sub-group of green female supporters drove the observable changes in attitudes: "In fact, (female) Green supporters are driving the observed phaseout relief effect" (Goebel et al., 2015, 1161). The authors conclude that a nuclear accident can impose negative externalities not only to the local population, but can ripple to distant countries around the world. This study also showed that the proportion of people who perceive themselves as 'very risk averse' increased after the accident the closer the people lived near a German nuclear power plant.

An analysis of media attention in the U.S. after the Fukushima accident indicated that an increase in media attention leads to a decrease in nuclear acceptance. The authors assume that after the accident anti-nuclear ideologies and environmental views effectively mediated the effect of the accident (Besley and Oh, 2014). The authors also identified a change in individual's risk and benefit perception in the U.S., assuming that individuals changed their opinion about governmental institutions responsible for nuclear energy. Also in a German study by Arlt and Wolling (2015), a media analysis clearly indicates that agents in the governmental and economic sector changed their attitudes from an a-priori nuclear prone position towards a more nuclear skeptical position (Arlt and Wolling, 2015, 12). Pro-nuclear positions were only held by the nuclear energy industry whereas most public actors focused on skeptical topics, such as risk and security. The authors conclude that media coverage was a main driver in attitude changes among the German population.

5.6. An integrative model of risk perception

I want to close the section on risk perception by introducing the integrative model of risk perception developed by Renn and Rohrmann (Renn and Rohrmann, 2000b; Renn, 2008, 141–144). According to the author's view, and shown in my work, risk perception is a multi-facetted concept shaped by individual as well as social factors. Individuals try to integrate attitudes about risks into their existing and consistent belief system. The socially constructed views of risk can be perceived as more or less strong a-priori attitudes that can be changed through new hazard specific information, such in a case of an accident, but it remains unclear to what degree new information is changing pre-existing attitudes on specific risks.

The integrative framework as described by Renn and Rohrmann (2000b) is an attempt to combine the existing mixture and variety of different scientific perspectives

protection? Are you concerned about it? (a) Very concerned, (b) Somewhat concerned, (c) Not concerned at all" (Goebel et al., 2015, 1144).

and school of thoughts, taking into account the whole spectrum, ranging from intuitive individual heuristics to culturally shaped worldviews (compare Figure 10). The framework is designed not only to focus on the individual person and its characteristics as the relevant information processor, but also to integrate higher aggregated social and cultural influences. The framework consists of four levels; each level is embedded in the next higher level: "to highlight the mutual contingencies and interdependencies among and between individual, social and cultural variables" (Renn, 2008, 141). Furthermore, each level contains individual as well as collective manifestations of risk perception. The first level includes collective and individual heuristics of information processing. The second level includes factors for cognitive and affective information processing of risks. The third level comprises social and political institutions and socio-political individual factors. The fourth level includes the cultural background and worldviews that shape individual's identity.

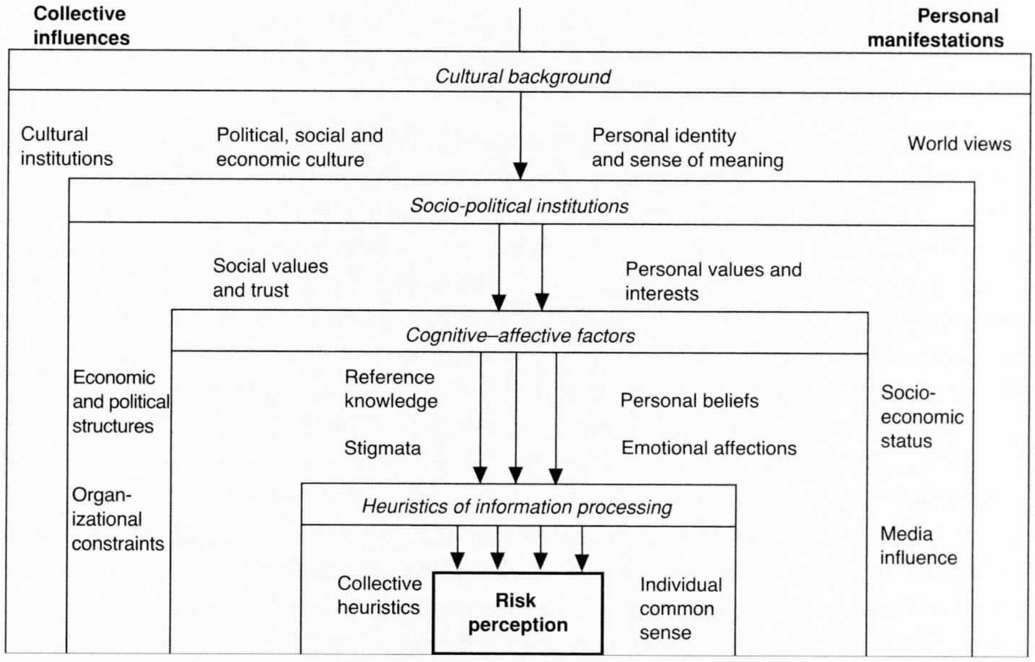


Figure 4.4 *Four context levels of risk perception*

(Source: Renn, 2008, 141, Fig. 4.4)

Figure 10: Integrative framework of risk perception.

The first level of collectivistic and individual heuristics represents the mechanisms individuals use to derive and to form their judgements about risks (compare Section 4.2.1). Heuristics are common-sense reasoning patterns that have been developed in human history over the course of evolution. They are independent of the actual risk source and can be applied broadly. Renn also mentions that heuristics may differ across cultures, even though he states that across cultures heuristics show a "surprising degree of universality" (Renn, 2008, 141). Studies indicate that heuristics are common in every day life problem solving processes (c.f. for example, Gigerenzer, 1991, 2008b). Even though heuristics are an intuitive approach to problem solving, individuals are able to learn to adopt specific heuristics to specific problems and to use additional knowledge from logical reasoning or statistical procedures to adjust their a-priori intuitive judgements (Braga et al., 2015). Renn concludes on the usage of the first level of his framework: "Regardless of the normative value that these heuristics may offer, they represent primary mechanisms of selecting, memorizing and processing signals from the outside world and pre-shape the judgements about the seriousness of the risk in question" (Renn, 2008, 142).

On the second level are collective-affective factors that shapes attitudes about a specific risk source. The qualitative characteristics of a risk source can be examined by using psychometric variables, such as familiarity, dread potential, or personal control (compare: Section 4.2.2, Section 4.2.5, and Section 4.2.7). Integrating different characteristics forms the perceived seriousness and dread potential of a risk, that can differ between societies (Rosa et al., 2000). On the individual level, emotions play an important role in forming risk attitudes (Loewenstein et al., 2001; Slovic et al., 2002; Finucane et al., 2000a; Peters et al., 2004). Especially when conflicting information is provided, affective signals are used when judging risk. On the collective level stigma effects (compare Section 4.2.8), intertwined with emotional and communicative processes, are a collective response to avoid reactions to risks.

The third level, the socio-political institution level, entails scientific approaches that explain the judgements of risks by referring to the social institutions that are perceived by individuals to be associated with a risk (compare Section 5.2.3). The most important aspects are trust in political and social institutions that govern risks or the perceived benefit of a risk. On the individual level, personal values that form judgments of risk perception as well as social attributes such as the socio-economic status are expected to influence risk attitudes (compare Section 5.3). Risk on this level is evaluated through social mechanisms that can be based on concepts of equitable distribution of risks (Linnerooth-Bayer and Fitzgerald, 1996; Knight and Warland, 2005). The role of media, as well as an individual's social background are forming different views on risks (Wahlberg and Sjöberg, 2000).

The fourth level is the cultural background (compare Section 5.2) that has been described by proponents of Cultural Theory (Douglas and Wildavsky, 1983; Thompson et al., 1990; Cornia et al., 2014). Even though Renn holds a skeptical view of this approach, due to methodological aspects (c.f., also for cautious remarks on the explanatory power of cultural theory Johnson, 1991; Sjöberg, 2000), he perceives the described four or five prototypes in Cultural Theory as an useful approach: "All authors agree, however, that specific culture-based preferences and biases are, indeed, important factors in risk perception. The disagreement is about the relevance of the postulated four or five prototypes within the realm of cultural factors" (Renn, 2008, 144).

For future research Boholm (1998, 160) is summarizing the relevance of individual as well as for cultural factors to get a better understanding of the multi-facetted nature of risk attitudes: “Fields for cross-national research into the perception of risks that augur well for the future, appear to be the role of ‘background factors’ such as gender and social marginality, education and occupation. Broad ‘ideological’ issues, especially those relating to understandings of political matters and trust in the orders of dominance and authority, might also be predicted to attract increasing attention.”

6. Empirical research I: Cross-national comparison of nuclear risk perception: Nuclear risk perception in the United States, Great Britain, France, Germany, and Japan before the Fukushima Daiichi accident

6.1. Introduction: atoms for peace

In New York City on December 8, 1953, United States' President Dwight D. Eisenhower held a speech before the General Assembly of the United Nations titled 'Peaceful Uses of Atomic Energy'. His address became know as the 'Atoms for Peace' address. Eisenhower proposed using nuclear knowledge and nuclear technology peacefully and suggested building international institutions, such as an "Atomic Energy Agency" responsible for distributing fissionable materials and knowledge to places in the world in need of electrical energy. From his point of view, the aim was to make nuclear technology a means of providing prosperity and wellbeing for humanity to "adapt it to the arts of peace" (Eisenhower, 1953)[57]. The former five-star general of the United States Army in World War II suggested institutional efforts to stop the nuclear arms race. He most of all points out that the Unites States, as the former monopolist of nuclear knowledge, is willing to help motivated partners all over the world to use nuclear technology as an element for peace to stem the symptoms of a rising war that is separating the world in two blocks: "move out of the dark chambers of horror into the light" to create "peace and happiness and well being." "In this enlightened age," as the President continues to emphasize in 1953, "the great powers of the earth, both of the East and of the West, are interested in human aspiration first, rather than in building up the armaments of war."

Nuclear technology bears the power to bring peace across the world, that is the basic message Eisenhower addresses in his speech. In his speech the president of the United States also mentioned the "fearful atomic dilemma," indicating that the development of a nuclear bomb had driven the world into a Cold War. To examine this dilemma in more detail in this introduction, I want to briefly summarize the development of nuclear technology. How could nuclear technology develop into an important technological means that on one hand provides a hazardous potential to destroy humanity, the "nuclear holocaust" (Giddens, 1990, 8; Jasanoff, 2006, 30) as described in Section 3, and on the other can be seen as able to provide prosperity and peace?

In Alamagordo, New Mexico, on July 16, 1945, the United States successfully tested the first atomic bomb. On August 6, 1945, the first atomic bomb was dropped on Hiroshima in Japan and three days later a second atomic bomb was dropped on Nagasaki, only few days before Japan surrendered on August 15, 1945, the end of World War II. A

[57] Document available at `http://www.eisenhower.archives.gov/all_about_ike/speeches/atoms_for_peace.pdf` (accessed October 15, 2015).

huge military, industrial, and scientific complex, with a fast investment of money, called the Manhattan Project, made it possible to create an atomic bomb before the end of World War II. In August 1949, the Soviet Union successfully tested their first atomic bomb, accelerating the nuclear arms race. In Arco, Idaho, in December 1951, the Experimental Breeder Reactor I (EBR-1) produces the first small amount of electric power. In Obninsk, Soviet Union, in 1954, the reactor AM-1 (called Atom Mirny – peaceful atom) started to operate. In 1953, the first Pressurized Water Reactor (PWR) Mark 1 designed for the first nuclear submarine USS Nautilus started operating and after President Eisenhower signed the Atomic Energy Act of 1954, the civic nuclear power program started 1955 with the Power Demonstration Reactor Program and experimental reactors started supplying electricity in Santa Susana, California and Shippingport, Pennsylvania in 1957.

In the late 1950s, it seemed that the atom had created a world order without a war between the two super powers, the U.S. and the Soviet Union. In 1956 Alvin Weinberg calls that situation a "Thermonuclear Peace" (Weinberg, 1956, 302) and scientific knowledge enables that peaceful way of living. From his point of view, the merits of nuclear technology will be an important element of peace for all human beings. No radical political ideology, neither nationalism nor communism, will become dominant in an age of abundance and unlimited energy supply, so his opinion. For Weinberg nuclear technology is the beginning, the "advent," of a new "Scientific Era," a "Scientific Revolution." An era without wars, because science will provide enough for everybody: "science making an abundance available to all" (Weinberg, 1956, 301). The optimism Weinberg expresses is driven by the conviction that in the near future new revolutionary progresses in science will solve all technological problems and that all practical and social problems are solvable through technology and scientific reasoning. In the same enthusiastic way Admiral Lewis L Strauss mentioned, in 1954, to the National Association of Science Writers, New York City, that nuclear energy will soon be an energy "too cheap to meter" (Freudenburg, 1988, 48).[58]

Nevertheless, freeing the atom bears very obvious its own risks; it is a "Faustian bargain" between a technological elite and society, as Weinberg emphasizes (Weinberg, 1972, 33). The scientific merits of nuclear technology need specific social conditions, some of which have not been existing. According to Weinberg, nuclear technologists provide cheap and clean energy in return ask for social vigilance and long lasting social

[58] At that time Strauss was the Chairman of the United States Atomic Energy Commission who saw the atom as an (technical) element of a peaceful future. The quote in full length as published on the New York Times, August 7, 1955 indicates that cheap energy is perceived as an important aspect of wellbeing, prosperity, and peace for future generations: "It is not too much to expect that our children will enjoy in their homes electrical energy too cheap to meter; will know of great periodic regional famines in the world only as matters of history; will travel effortlessly over the seas and under them and through the air with a minimum of danger and at great speeds, and will experience a lifespan far longer than ours, as disease yields and man comes to understand what causes him to age. This is the forecast of an age of peace." (Source: `http://media.cns-snc.ca/media/toocheap/toocheap.html` (accessed October 29, 2015))

institutions to take care of the possible risks of nuclear accidents, nuclear transport, and nuclear waste disposal in the future. He compares his proposed bargain with society with the nuclear weaponry technology that brought peace in exchange for the existence of a hazardous technology. The new technology also established new social structures, "a military priesthood," as Weinberg calls the institutional structures necessary to control and to manage the arsenal of nuclear weaponry. In 1972, 20 nuclear power plants existed in the U.S. producing less than 3 % of the total electricity in the U.S., with 40 more nuclear utilities to be ordered a year later. At that stage of nuclear development, Weinberg prophesied similar demands, such as vigilance and long lasting institutions, for a society that decided to use nuclear technology not as weaponry but for energy production. Technologist, from his point of view, can never offer certainty about nuclear safety in the future, but the best knowledge and means to safely create nuclear energy by "creating a continuing tradition of meticulous attention to details" (Weinberg, 1972, 34), by practicing vigilance and by becoming a technological priesthood for peaceful nuclear energy usage. However he knows that this technology needs a social commitment to create an infinite stable social system, a "permanent social order," until a new and better technology is invented to provide energy for society to a lower level of risk (Weinberg, 1972, 34).

Weinberg concludes that scientific means are limited and nuclear technology cannot be considered a safe technology. The matter of nuclear safety is a questions that is beyond the, best and most responsible, scientific scope and judgement because it has "trans-scientific elements" (Weinberg, 1972, 34). Depending on vigilance and a stable social order, Weinberg is also aware that not the scientific community nor political elites, rather society is responsible for deciding about the future of nuclear energy: "The society must then make the choice, and this is a choice that we nuclear people cannot dictate. We can only participate in making it. Is mankind prepared to exert the eternal vigilance needed to ensure proper and safe operation of its nuclear energy system? This admittedly is a significant commitment that we ask of society. What we offer in return, an all but infinite source of relatively cheap and clean energy, seems to me to be well worth the price" (Weinberg, 1972, 34). For Weinberg it is still a "Faustian bargain" and at the end nuclear is not a technology "too cheap to meter," as Strauss claimed it. Nuclear has its price and it is society's choice to judge the price and to decide to accept the bargain or not, civic vigilance in perpetuity. Even though Weinberg is an ardent proponent of nuclear technology, he addresses the social requirements for a safe usage of nuclear technology.

Weinberg also points out that all social actors within a society and not a technocratic elite is responsible for deciding how nuclear technology should be used in the future. Therefore, public nuclear risk perception, as I conclude, can be perceived as an indicator of public acceptance of nuclear power (cf., Siegrist and Visschers, 2013). Furthermore, comparing the historical development of nuclear technology within different societies can help to better understand to what degree nuclear technology is accepted as means for a country's prosperity and peaceful development. In this chapter I will examine in more detail how dangerous nuclear technology is perceived in five selected societies. I compare nuclear risk perception in the United States, Great Britain, France, Germany, and Japan using data conducted in 2010, before the nuclear accident in Japan on March 11, 2011. My aim is to examine the social foundation of nuclear risk perception. I chose five developed countries because these countries created ambitious civil nuclear programs in three continents. In these five countries, 223 nuclear power stations were under operation in 2015.[59]

The United States and Great Britain were the driving forces behind the Manhattan Project and the development of the nuclear bomb in World War II. The technological knowledge developed in the U.S. was shared between both countries after World War II, enabling Great Britain to develop their own nuclear program in 1952. France developed their own nuclear weapon program in 1960. The U.S., Great Britain, and France are three of the five states that are recognized as nuclear weapon states by the Treaty of Non-Proliferation of Nuclear Weapons, beside Russia and China. Germany is the largest European country that decided to stop their civil nuclear energy programme after the Fukushima Daiichi nuclear accident. Japan developed a huge nuclear project and operates the largest number of nuclear power plants in an Asian country. The Fukushima accident brought the nuclear project to a temporary stop. To compare nuclear risk perception across different countries I analyze social factors that influence risk perception and compare the results across the five selected countries using logistic regression models. To better understand the historical development of nuclear technology in all five countries, I recapitulate the development of the nuclear project in each country and also social reactions to that development since the beginning of the nuclear age after World War II. In Weinberg's language, I want to better understand who is claiming to be the priesthood of nuclear technology? In the historical revision of the trans-scientific development of nuclear energy, I want to know: How was the nuclear energy program established and institutionalized in each country? Did a technocratic elite establish nuclear technology or was is a democratic process? How did each country's anti-nuclear movements develop parallel to the development of nuclear energy? Was the anti-nuclear movement able to influence the nuclear project to make it a democratic and not a technocratic project?

6.2. Historical overview of the nuclear projects and anti-nuclear movements

In 1980, one year after the Three Mile Island nuclear accident in the United States, Alvin Weinberg was less optimistic about public support for nuclear energy, because nuclear

[59] In 2015, the U.S. had 99, the UK had 15, France had 58, Germany had 8, and Japan had 43 nuclear power station under operation (Japanese's nuclear reactors listed as operational, are not producing electricity since the accident). A total of 442 nuclear power stations were world wide under operation in 2015. Source: IAEA PRIS database, `https://www.iaea.org/PRIS/home.aspx` (accessed on March 13, 2016)).

power seemed to be perceived as having been imposed on society by a dominant elite. He writes “I am aware of a current mood of rejection of electricity as being the energy form epitomizing centralization, corporate authoritarianism, and bigness” (Weinberg, 1980). Byrne and Hoffman (1988) argue in their article ‘Nuclear Power and Technological Authoritarianism’ that in the case of the U.S., France, and Great Britain collaborative coordination and trans-national technological transfer between governmental, scientific, industrial, and military institutions were an important element in nuclear energy development. From a governmental point of view, in his farewell address U.S. President Eisenhower (1961)[60] calls that institutional conglomerate that guarantees peaceful development in a technological era the “military-industrial complex,” with an important contribution of scientific knowledge: “research has become central” as he emphasizes.

Byrne and Hofmann argue that a consortium of scientific, military, and industrial interests is interested in the development of nuclear energy. This process is not a democratic process as the authors emphasize (Byrne and Hoffman, 1996, 2). On the contrary, institutionalized nuclear development undermines democratic principles and ideals. Furthermore, the nuclear project has created authoritarian structures in politics and economy promoting authoritarian scientific institutions. Nuclear technology has always been a promising technology with acceptance in the population. Social protest against nuclear technology remained limited, also because nuclear technology is a symbol of the predominant technological progress that created today’s developed societies (Byrne and Hoffman, 1988). To what degree the development of nuclear power, though accepted by parts of the populations, has been a democratic process cannot clearly be differentiated. The existing political setting, or as Kitschelt calls it, the “political opportunity structure” (Kitschelt, 1986, 58), in a country, allowed state authorities and civil society actors to influence the development of a country’s nuclear energy program to a different extend.

In the aftermath of the Three Mile Island accident in 1979, Alvin Weinberg saw the nuclear project in danger and jopardized by an ill-informed and hysteric public and scientific community, people who are not able to rationally process the possible consequences of radiation, and, hence, call for irrational actions. From Weinberg’s point of view, this irrationality is a “modern form of witchcraft” (Weinberg, 1980, 403) that exaggerates the consequences of a reactor’s radiation and ignores the hazardous potential of natural radiation. According to Weinberg, the nuclear energy system can only survive if public’s exaggerated hysteria can be tamed. Complaining about public reactions against nuclear power he says: “It took two centuries to get over our fear of witches. I hope it will take much less than that to overcome our fear of this newer witchery” (Weinberg, 1980, 403). Byrne and Hofmann assume that the apparatus of technological authoritarianism will answer to any accident with increased efforts to justify the technological development of interests. From the authors’ point of view, that means, that because of nuclear technology technical authority will continue to replace political and democratic authority; it

[60] Document available at http://www.americanrhetoric.com/speeches/PDFFiles/Dwight%20D.%20Eisenhower%20-%20Farewell%20Address.pdf (accessed, 15. October 2015).

means that the national security institutions will be granted more competences; meaning in turn that the technological ideology and the calling for more progress and development will be promoted by the authoritarian structures to undermine and further limit public autonomy and civil rights (Byrne and Hoffman, 1988, 668). In some countries, such as (West) Germany and to some degree in the U.S., anti-nuclear movements were able to more or less successfully stop or to slow down the development of the nuclear project. Beside opposition, there is also support for nuclear technology in these countries, especially among certain sub-groups within the population, as I will show in my research.

Nuclear technology, has been and I suppose will always be, a topic that creates tension in society. I continue to present in more detail the historical development of the national nuclear projects and the anti-nuclear movements. The comparison of anti-nuclear movements in all five countries has its limitations and is not strictly following a deep and systematic comparison of different key aspects in each country, because I focus on an empirical comparison of survey data. Even though I mention the influence of the political context within which social protest of the anti-nuclear movement is taking place, I neglect for example to systematically compare a country's existing political opportunity structure (compare for a systematic evaluation for example Kitschelt, 1986; Rucht, 1990; Carmichael et al., 2012) or do not control for socio-political macro-variables, I then could use in a hierarchical linear model design (compare for example Jenkins et al., 2008). Yet to better understand today's observable differences in survey data, for me it is important to also understand the historical development of the anti-nuclear movement and historically grown institutionalized structures in society.

Independent of the anti-nuclear movement, in the case of any social protest or social movement, it is important to mention that according to Kitschelt (1986, 63-64) national authorities can better implement policies first, if the state is ruled by centralized governance structure and not for example by a federal split of competences. Second, if the state is controlling key market institutions and economic resources, such as the finance sector, enabling the executive bodies to influence policies independent of the existing market mechanisms. Third, if the judicial opportunities are low, i.e. if the judiciary is not independent of the executive decision making bodies, national authorities are to a high degree immune against third parties who take legal actions to stop policy implementations (cf. for example De Fazio, 2012; Doherty and Hayes, 2014). The role of state owned media is also an important aspect that is directly influencing public acceptance of policy implementations, as Rucht (1990, 212) is mentioning.

6.2.1. United States

The historian, Dieter Rucht remarks that the anti-nuclear movement in the U.S. became a broad social movement after the energy crisis in 1973 – 1974. As a consequence of the rising anti-nuclear movement, political institutions in the U.S. started a debate over the country's national energy policy (Rucht, 1990, 198). At that time, the Atomic Energy Commission (AEC), founded in 1946 to develop a peaceful nuclear energy project, was responsible on one hand to promote nuclear technology, and on the other to regulate and control nuclear technology. This double function raised doubts among the public and policy makers. Among the civil society in the U.S., established organizations such as the Union of Concerned Scientists or the Sierra Club and other organizations, such as Friends of the Earth or Natural Resources Defense Council, raised their critical voices and started to argued against nuclear technology and its regulatory bodies. After 1974, the anti-nuclear movement coordinated themselves better and established a firm network. At the same time doubts about nuclear technology's safety raised concerns among the population. Motivated by the anti-nuclear mass movement and well coordinated anti-nuclear networks, local groups took more and more legal actions against nuclear projects, such as new nuclear sites, transport routs or nuclear waste deposals. Access to the mass media played an important role in the success of the anti-nuclear movement in the United States. The anti-nuclear movement at that time could activate the mass media, even if, such in the case of a referendum in California, the initiative was not successful. Beside the consolidation of the anti-nuclear movement (e.g. the nation wide Critical Mass Conferences where held in Washington D.C. in 1974 and 1976) and legal intervention there was other direct action taken against nuclear sites, such at Seabrook, New Hapshire in 1976.

In the eyes of Rucht, this protest culture was also a general protest against established political power structures and a technocracy prone to large technology projects (Rucht, 1990, 200). Moreover, the anti-nuclear movement developed into a decentralized but well connected organization that used different strategies and forms of action in all levels of the political system to stop the development of nuclear power: "Nuclear power production faced a full-blown oppositional movement with an elaborated ideology, sophisticated arguments, a decentralized but effective organizational structure, and a clever use of strategies and forms of actions" (Rucht, 1990, 200). Similar to Rucht, also Joppke argues that the anti-nuclear movement in the U.S. was a movement of fragmented and well organizes groups reflecting well the decentralized political structure of the political system in the U.S. (Joppke, 1993, 191). The political opportunity structures in the U.S. is an open and inclusive system allowing interest groups to organize themselves and to take legal actions against nuclear projects (Dryzek et al., 2002; Kitschelt, 1986, 661).

The slowdown of nuclear projects in the 1970s in the U.S. also happened due to structural changes in the energy sector. Beside public opposition after the energy crisis, the nuclear industry market faced also an economic, institutional, and structural crisis. The industry faced an increase in costs and higher safety standard, and was constantly struggling with construction delays. At the same time, the demand for electricity was lower than expected. As a consequence, the utilities in the U.S. cancelled more than hundred nuclear reactors in the 1970s and 1980s (Yang, 2011, 3025). Structural reasons such as a fragmented industry and low degrees of standardization among nuclear reactors led to an increase in costs due to low levels of technological learning among the nuclear power plant operator and the producer.

The Three Mile Island nuclear accident in Pennsylvania on March 28, 1979 accelerated the slow down of the development of nuclear power in the United States. Large protests against nuclear technology took place in Washington D.C. and New York City. At that time the anti-nuclear movement established itself as a watchdog able to mobilize protests against nuclear power. Even thought, the nuclear crisis was not because of the anti-nuclear movement, Rucht still argued that "the anti-nuclear movement in the USA has won the battle" (Rucht, 1990, 200). According to Yang (2011, 3027-3028) the U.S. are not expected to successfully start a nuclear renaissance in the 21st century. From the author's point of view, the market in the U.S. is too fragmented and lacking common standards leading to high costs and construction delays. Because of lower energy demand and limited regional accessibility, new nuclear projects are small (on average in the U.S. there are two reactors per site) lowering the ability to learn from previous projects at the same site. Hence, the industry faces a great financial risks installing expensive nuclear technologies. Unlike in France and in China, the government in the U.S. is not directly backing financially nuclear energy projects. Furthermore, in the U.S. regulatory bodies are not able to prescribe a specific technology to be built but depend on the decision making process of private investors, most often regional energy consortiums with many stakeholders. From my point of view, the given economic, political and social structure in the U.S. makes it quite unlikely that nuclear technology will be revitalized in the 21st century. The nuclear project in the U.S. has passed too many structural changes since the Manhattan Project started in 1942. In the U.S., the postwar period before the energy crisis was characterized by a corporatist political structure, independent of public interests. New legislations broke that unyielding process and created a more pluralistic process, open for antinuclear interests to influence the licensing process of new nuclear power plants. This erosion of corporatism resulted in higher costs for utility operator, who did not get financial support from state authorities. As a result, the cancelation of already ordered nuclear power plants increased and finally stopped after the Three Mile Island accident in 1979 (Hatch, 1996, 207). Even though the U.S. was still the country with the most operating nuclear power plants in 2015 (99 out of 442) it is not be expected that this number will rise dramatically in the future (currently there are five power plants under construction, all at existing sites, and 33 have been shut down permanently) (IAEA International Atomic Energy Agency, 2015). Moreover, the share of nuclear energy of the total energy production in the U.S. in 2015 was according to the International Atomic Energy Agency (IAEA) at 20 %.[61]

6.2.2. Great Britain

In 1954 the UK Atomic Energy Agency (UKAEA) was founded and in 1955 in the White Paper 'A Program of Nuclear Power' Great Britain's nuclear energy strategy was

[61] Source: IAEA International Atomic Energy Agency, 2015, https://www.iaea.org/pris/CountryStatistics/CountryDetails.aspx?current=US (accessed March 15, 2016).

presented to the decision making bodies. Already in 1947, it was decided to build a British atomic bomb, resulting in the first atomic weapon test in October 1952 in Monte Bello, Australia (Hill, 2013, 347–348). In 1957 the first British H-bomb was tested on Christmas Island. The first nuclear commercial power plant to open in Great Britain was Calder Hall in 1956. Soon after, in 1957 the first nuclear accident at Windscale happened. In 2015, 15 nuclear power plants were still operating and 30 were permanently shut down.[62] The last nuclear reactor connected to the grid was the Sizewell reactor build in 1995. Great Britain is continuing to build nuclear power plants with foreign partners. In October 2015, a deal with a Chinese consortium was signed to build two new nuclear power plants to be connected to the grid in 2025.[63]

In the early stages of nuclear power, the development of nuclear energy was in the hands of "consummate administrators" (Hill, 2013, 3) working for the UKAEA. The UKAEA was an autonomous institution, independent in their decision making power of elected politicians. Similar to the UKAEA the Central Electricity Generating Board (CEGB), a nationalized industry, decided autonomous about electricity generating matters in Great Britain. Elected politicians at that time had almost no or little influence on national energy decisions. The authorities worked for elected ministers, but the decisions on nuclear power were taken by the authorities and not by the ministers (Hill, 2013, 3). In 2013, according to Hill (2013, 2) all nuclear facilities in operation are owned by Électricité de France (EDF) and in Great Britain there are no companies able to build new nuclear power stations. Great Britain needs foreign partners to build new nuclear power plants.[64]

In the 1950s, in the early period of nuclear power, the public, as well as the local communities, more or less supported the technology. In the 1970s and 1980s, public's support for nuclear energy changes to opposition: "Environmental groups began campaigning against nuclear power using arguments which were distinctly suspect from a technical point of view, but which resonated with the general public mood" (Hill, 2013, 4). Already in 1958 the Campaign for Nuclear Disarmament (CND) started its political protests (Veldman, 1994, 115) in Great Britain. Among its most well known supporters were Bertrand Russell and George Kennan. The protest in Great Britain was, according to Veldman, based on a worldview that was suspicious to technological development and rejected the idea that scientific knowledge, especially empiricism, was the ideology to finding truth. There was a tendency towards "transcendence" and the "supernatural" in the British environmental movement, as Veldman observes (Veldman, 1994, 2-3). The driving idea behind the anti-nuclear protests was not only to campaign against a dangerous technology, it also was an idealistic movement aimed at creating a better society. In the 1950s, the CND turned out to be a middle-class movements mobilizing women

[62] Source: IAEA International Atomic Energy Agency, 2015, `https://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=GB` (accessed March 15, 2016).

[63] Source: `http://www.world-nuclear-news.org/NN-China-agrees-to-invest-in-new-UK-nuclear-plants-2110155.html` (accessed March 15, 2016).

[64] The British design of nuclear power stations, mostly built in the 1950s and 1960s, were gas-cooled reactors, a design not built anymore.

and men from different social backgrounds, able to mobilize mass protests with several thousand participants on various marches. The CND was a closed network of independent organizations, first campaigning against the British nuclear weapon program, then in the 1980s, fighting against U.S. cruise missile deployment in the UK (Veldman, 1994, 117). According to Veldman, the CND movement in the 1960s wanted to see Britain as a peaceful country, without nuclear technology, the neutral power between the two fighting superpowers: "Nuclear disarmament would allow Britain to revivify its own culture. Britain could then not only lead the neural nations, particularly the developing areas, into a more peaceful and prosperous future but also serve as a mediator between the two superpowers" (Veldman, 1994, 118). The topic of nuclear disarmament was also controversially discussed in the Labour Party between left-wing opponents and right-wing proponents of a British atomic bomb (Brandon, 1987, 45), which continuously fueled concerns of a broad anti-nuclear movement at that time.

The anti-nuclear movement in the UK, was also a movement protesting against the undemocratic political process that went along with the development of the atomic bomb and its institutional structures. Both the decision to start the program, as well as the final decision to use the bomb, was a nondemocratic process as the CND claimed: "The Bomb threatened to destroy the very democracy that it was designed to protect" (Veldman, 1994, 201). In the heart of the campaign's ideology was also the distrust of the logic of scientific reasoning and the rational logic of cold war strategy. People, as the campaigners claimed, should trust their feelings: "CND saw that one of its central missions was to convince ordinary individuals that they knew better than the experts, that the almost instinctive emotional revulsion against the idea of nuclear war should be trusted as much as or more so than any strategic calculation" (Veldman, 1994, 202).

The CND anti-nuclear movement dried out in the 1970s. The British anti-nuclear movement was born again at the beginning of the 1980s when the Greenham Common started their protests. The Greenham Common was a protest by women who organized a camp to protest against nuclear missiles placed at the Greenham air base. This revival of the anti-nuclear movement led to an increase of local organizations and peace groups throughout the country. Any ecological or anti-nuclear involvement on the political level depended on the commitment of the Labour party, as Brandon 1987, 98 states because an ecological Green party could not be established. According to Koopmans and Duyvendak the British anti-nuclear movement was a "very weak" movement because it was not able to actually delay or stop the development of nuclear power plants. The reduction of the nuclear energy program in the 1980s was not due to pressure from the anti-nuclear movement but because of other difficulties in the nuclear energy sector (Koopmans and Duyvendak, 1995, 246 (citing Rüdig, 1990)).

The anti-nuclear movement, as part of the environmental movement in Great Britain, could not develop strong influences in national politics because the British political system was, as described above, an informal technocratic system, with no influence of civil society actors on nuclear issues. In the 1980s, an "authoritarian liberalism" (Dryzek et al., 2002, 675) led to an active oppression of civil society actors and institutions dealing with environmental issues. The political opportunity structure, such as the voting system, did not allow an environmental social movement to develop and to enter the political sphere (Dryzek et al., 2002, 676). Great Britain, hence, can be evaluated as an exclusive political system with low political opportunity structures to establish an effective anti-nuclear movement.

6.2.3. France

In France political, military, scientific, and industrial elites were able to establish an electrical energy system that is dominated by nuclear power. In 2015, 76 % of the total electricity production was produced by 58 nuclear power plants in operation, with one nuclear power plant under construction in Flamanville (IAEA International Atomic Energy Agency, 2015)[65]. The French nuclear electricity project started after the energy crisis in 1974 and was planned, executed, and controlled by centralized and state owned institutions. After the energy crisis, the French government declared the official policy of "*tout electrique, tout nuclèaire* (only electricity, only nuclear power)" (Rucht, 1990, 201). The design of the nuclear reactors was standardized and the sites larger compared to the U.S., enabling more plants to be operated at the same site. Since the beginning of the nuclear project, Electricité de France (EDF) has been the only national utility running nuclear power plants and has been in charge of electrical power supply nationwide. This state owned utility is financially backed by the state, which almost completely eliminates the financial risks of building and running a nuclear power plant.

Due to new developments and rising public concerns about safety and environmental consequences, nuclear energy became a major public topic and entered the public sphere in France in the 1970s. Before the energy crisis, the anti-nuclear movement was a small movement with regional groups concerned mostly with ecological questions, among them nuclear energy. According to Rucht, the French anti-nuclear movement was the first movement that was active in Europe, starting its first protest in April 1971, in Fessenheim (Rucht, 1990, 200). In 1976, the anti-nuclear movement in France consolidated and grew with support from the local population scientific groups, but lacked support from national authorities and political institutions. The state owned medias held a pro-nuclear opinion and, so in terms of mass media coverage, anti-nuclear opinions did not get much of a platform. The support from governmental authorities was also lacking, all major political parties and trade unions held a pro-nuclear position. During a large, 66,000 people, anti-nuclear demonstration in Malville in 1977 the situation between the protesters and the police escalated. The event harmed the public credibility of the anti-nuclear movement in the future. In the years after 1977, the movement was not able to consolidate and failed to establish an ecological party. Rucht states that the movement in France has always kept its fragmented status also because it was based on strong individuals, divided by ideological cleavages and also driven by local separatists desires

[65] Source: `https://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=FR` (accessed March 18, 2016).

in Alsace or in Brittany. Only one nuclear project, the reactor in Plogoff, Brittany, was stopped 1981 due to public protests (Rucht, 1990, 203; Brouard and Guinaudeau, 2014, 143). The French exclusive political system (Kitschelt, 1986) and the low opportunity structures for the civil society to gain access into the political arena did not lead to a successful anti-nuclear movement and to no political participation in the political decision making process.

According to Jasper (1996), in France, the forging of a new nuclear energy industry was successful because it was actively managed by technocratic and industrial elites. The public authorities could suppress public concerns, especially through media control. As an example, Jasper refers to the Three Mile Island accident in 1979 when no critical voices appeared in French medias. The centralized management of the entire nuclear process led to lower costs of nuclear energy supply and strict regulation made the utility management more efficient compared to, for example, the U.S. Jasper argues, that a centralized government and its strong regulation institutions actively managed to make nuclear energy an energy source and created the success of nuclear energy in France: "The French managed to make their nuclear optimism a reality" [56](Jasper, 1996). An analysis by Mycle Schneider (2008)[66] states that in France a technocrat elite group of engineers, graduating from the École Polytechnique was the pushing power behind the project, more than the elected officials. According to the author, members of the Corps des Mines have been holding all key positions in the agencies controlling the nuclear project in France. Nuclear advisors of important political institutions, key positions in industry and key positions in the regulatory bodies are held by members of the Corps des Mines. The control of key positions by an elite circle and the monopoly of the electric utility company EDF allowed for centralized long term planning, independent of the actual political color of elected members of the government. More than that, the nuclear project in France never separated into an civil and a military project, as in the case of the U.S. According to Schneider, the administration of nuclear energy and nuclear weapons is still under the control of one institutional body (Schneider, 2008, 8).

The French nuclear program has been a success and structural circumstances prevented the nuclear project from a crisis, even after major nuclear accidents such as Three Mile Island, Chernobyl or Fukushima. Schneider summarizes: "There is no doubt that the French nuclear program represents a remarkable scientific, technological and engineering performance. The implementation of a complex chain of facilities from uranium mining to waste disposal, from uranium conversion to reprocessing, from uranium enrichment to reactor operation over a period of five decades is the result of undisturbed persistence. The program has been designed, developed and implemented under the guidance of a powerful technocrat elite, beyond governmental changes and outside parliamentary decisions and control" (Schneider, 2008, 38). The scientific project in France, like the Manhattan Project in the U.S., is an example of how the integration of science, media, the state, the military, and the industry can form a social complex that provides

[66] Available at http://www.nirs.org/international/westerne/258614beyondmythfr.pdf (accessed on December 15, 2015).

the free space to create knowledge, infrastructure, legislation, and the energy demand for a new technology. Since World War II in France, the military, technological, and economic aspects of the nuclear project have been an important element for French's national identity and "French grandeur", the feeling of national recognition within the community of sovereign national states (Hecht, 1998, 325).

6.2.4. Germany

Before 1974, the anti-nuclear movement in West-Germany (I will refer in the following to Germany) was marginal and only provincial. The dominant political practice was a corporatism between governmental actors and institutionalized actors within a federal state system. In 1975, anti-nuclear groups peacefully protested against the construction of a nuclear site in Wyhl, Baden-Württemberg and spontaneously and illegally occupied the construction site of Wyhl, resulting in an occupation of the site for several months. The state government of Baden-Württemberg feared negative publicity when using police force to remove protesters and started to negotiated with the joint protest groups of local farmers and citizens from the nearby university city of Freiburg. The Wyhl protests can be seen as the birthplace of a green movement in Germany, beyond traditional social class boundaries, as Brandon points out: "an unlikely political alliance was struck between country people concerned with the environment, largely conservative and middle-aged, and young left-wingers, with a backbone of religious support. This combination was to form the basis of the Green Movement" (Brandon, 1987, 95). The public authority was surprised by the social dynamics of the Wyhl incident and could not develop a clear strategy. In the same year, the license to build a nuclear power plant was withdrawn by a court.

The example of Wyhl indicates that protest was not the first step of a local community to raise concerns about a new to build nuclear power plant. Before the protest took place in 1975, people living in the area, mostly wine farmers and rural conservative people, were concerned. As a result they tried to address the state government directly to voice their concerns. The protests started as the local people found out that the leading heads in the federal government were deeply involved in the utilities and the construction companies. The realization that a political dialogue would not be successful and historical resentments against the federal state, combined with concerns about the environmental impacts of a nuclear power plant on the wine region, resulted in direct action against the nuclear site. The protests in Wyhl are an example how the protest culture of local and traditional communities against state authorities and non-democratic decision making processes shaped Germany's green movement to a large extent: "it is highly significant that one of the main catalysts of the Green Movement was the revolt by a traditional conservative and rural community against the 'technocrats'. Hence the issue of opposition to alien, technocratic forms of rule was a common denominator of the subjectivist protest by both the young well-educated middle classes and conservative elements" as Papadakis concludes (1984, 67). This early peaceful success of the anti-nuclear movement in Wyhl motivated further protests against nuclear projects in Germany, such as in Gorleben or Wackersdorf.

In 1977 the mobilization of anti-nuclear demonstrations lead to direct conflicts between groups of protesters and the police at places like Bronkdorf and Grohnde (Papadakis, 1984). Now facing well-prepared public authorities, the anti-nuclear movement tried different strategies to influence the decision making process. Direct action and sabotage were still a means to protest against the technology, along with promoting critical scientific voices. Furthermore, within the established political parties, critical allies were sought out and found. Education campaigners in affected neighborhoods started to inform the public about the potential dangers of nuclear sites for the community's health and safety. State authorities claimed that in return the energy is needed to guarantee prosperity and economic growth (Papadakis, 1984, 69). Moreover, in 1980, the green movements consolidated and a Green party was founded to directly influence political decision making processes in the future.

The Three Mile Island accident provided a media platform for Germany's anti-nuclear movement. The accident raised the discussion of alternative energy sources for Germany and the unsolved question of nuclear waste storage, in particular the planned nuclear waste depository in Gorleben. Rucht summarized that in the late 1970s the nuclear project in Germany became a widely discussed topic within institutions, such as the scientific community, trade unions, and established political parties (Rucht, 1990, 205). The nuclear topic never cooled down in the public sector and parliamentarian debates and remained a hot topic until the next major nuclear accident 1986 in Chernobyl. Governmental institutions at the state and federal levels lost credibility by their reaction to this event. The Green party and large groups in established parties such as the Social Democrats (SPD) or the Liberal Party (FDP), started taking an anti-nuclear positions. The nuclear project slowed down in Germany and never found strong support after Chernobyl. Most recently, after the Fukushima accident in 2011, the conservative government shot immediately down old power plants and committed itself to nuclear phase-out by 2022, continuing the plan to shout down all power plants by 2021 that had already been established under the first Social Democrat/Green party federal government in 2002. Prior to the Fukushima accident, the government, under chancellor Merkel, took a pro-nuclear position by allowing nuclear utilities to operate longer than 2021 and rethink the decision of a nuclear phase out in Germany. As a result, protest against nuclear power continued in the years 2008 till 2010 from direct action against nuclear waste transports in Gorleben to mass demonstrations in Berlin and Munich in 2010, and, for example, a human chain between two distant nuclear power plants in Krümmel and Brunsbüttel. From my point of view, the anti-nuclear reactions with mass protests after the Fukushima disaster in Germany, are not sudden explosions of irrational fear, but can be understood in this context as a continuous awareness of nuclear danger that has been part of the people's protest culture since the beginning of the nuclear project in Germany in the 1970s.

The nuclear project in Germany can be called 'ended', though a technology, such as nuclear technology, can never be called 'ended'. In the history of Germany's nuclear projects mostly private companies, such as Siemens and state owned private utilities worked together to develop peaceful nuclear technology. The federal government played an important role in creating this cooperation in order to bring nuclear power to commercialization. In 1955, a Ministry for Atomic Questions was established to coordinate scientific, industrial, and governmental interests and resources to set up a nuclear project in Germany. In addition the German Atomic Commission, was established. The idea of being less independent on important energy resources using nuclear energy was supported by all established major political parties in Germany till the 1970s. After the energy crisis in 1973–1974, the nuclear plan was to build 50 more nuclear power plants (Hatch, 1996, 208–209).

At that time Germany's nuclear project, a state supported industrial cooperation, was slowed down because of the successful strategies of the anti-nuclear movement. According to Joppke, because of the tight interests of the federal as well as national government and industry, the anti-nuclear movement in Germany turned to direct action, also as a protest against the authoritarian strong executive state (Joppke, 1993, 191). Germany's legal system supported successful protests. The German legal court system acts on the state as well as the federal level, offering more opportunities to access the legal system and to slow down the licensing process (Kitschelt, 1986, 66). In Germany, unlike in France, a atom law existed and prioritized safety above economic considerations (Wiliarty, 2013, 290). Beside the favorable court system and legislation the electoral system in Germany motivated cooperation between environmental groups to reach the 5 % threshold to gain access to the federal or state governments. In 1980, the Green Party was formed by environmental activist groups and soon gained significant political influence becoming a powerful political institution for the anti-nuclear idea, resulting in the fist nuclear phase-out legislation in 2002, by the fist Social Democrat and Green party government in German history. In Germany, within an exclusive political system, an environmental movement could develop and institutionalized itself within society and the political arena. Even though the closed corporate German of a strong state system existed, the legal as well as political opportunity structures of a federal government and a proportional voting system allowed also to establish strong civil society structures (Kitschelt, 1986; Rucht, 1990). The strong state also functioned as a constantly unifying element for the protest movement, allowing to mobilize people even after the environmental movement established itself as a Green party in the public sphere. This development allowed the movement to take at the same time direct and more radical actions against nuclear project as well as a to take a moderate participatory role in environmental politics (Dryzek et al., 2002, 671).

6.2.5. Japan

Similar to France, Japan relies on imported natural resources for country's energy demand. In 2010, Japan was the third largest producer of nuclear energy behind the U.S.

and France (Nakata, 2011, 110). After the energy crisis in 1974, Japan's decision makers decided to develop an ambitious national energy program based on nuclear energy, which started the nuclear energy program. As a result, before the nuclear accident in Fukushima, 30 % of generated electricity was produced by over 50 nuclear power plant throughout the country (Feldhoff, 2014). In 1963, a nuclear test reactor was built and in 1966, the first commercial nuclear power plant started operation. To develop Japan's nuclear energy program, the Japan Atomic Energy Commission was built and in 1956, this commission developed a long term strategy to develop a peaceful national nuclear program. The government supported the development of nuclear energy in Japan by spreading positive information about nuclear in the public medias, by supporting the nuclear industry and by supporting the scientific institutions responsible to educate nuclear engineers (Nakata, 2011, 99-100). The government also supported the local communities where nuclear facilities were built. Though the utilities were privately run, the Japanese government, especially the Ministry of International Trade and Industry (MITI), played an important role in supporting nuclear development. For Nakata it was a "bureaucrat-led economic structure" that controlled industrial development in Japan and the joint interests between the government and its institutions, including cooperations with the U.S. military, and the different industries allowed to make the nuclear project happening (Nakata, 2011, 100). Most recently the Ministry of Economics, Trade and Industry (METI) controls the nuclear industry, being on the one hand responsible for the national nuclear power development, and on the other hand to control and regulate Japan's nuclear safety.

From the very beginning, Japan's public was not involved in the nuclear power development, aside from deep skepticism about the consequences of nuclear radiation. As in other countries, the public was expelled from risk assessment processes when new sites for nuclear power plants where chosen. The consequences of radiation experiences after the nuclear bombs were dropped upon Hiroshima and Nagasaki at the end of World War II, created a great awareness of the negative impact of radiation on health. According to Nakata, the government addressed public concerns by creating shame, blaming civil society voices for being too skeptical, too vigilant, and creating unnecessary worries in a country that needs nuclear energy for society's future development and prosperity (Nakata, 2011, 101). All 55 nuclear power plants operating in 2010 were built next to the coastline and the sites were mostly chosen to be rural areas with declining population density, because that made it easier to gain the support of local authorities and to avoid public protests by providing governmental subsidies. Technical reasons, such as the water cooling process, also led to decisions for building nuclear power plants near the coastline.

According to Nakata (2011, 113) public protest against nuclear energy within the Japanese society was quite unlikely due to two main reasons. On the one hand nuclear sites were located in rather poor areas of the country and different financial incentives made it attractive to the local communities to collaborate with the nuclear industry and the government. Beside this structural reasons, it was and still is, a taboo to publicly criticize authorities. Japanese's society is a quite homogeneous society and still quite unified in topics related to security politics (Risse-Kappen, 1991, 493). Feldhoff therefore concludes that the role of the government as supporter for nuclear power has been an essential element that prevented the public from developing a nationwide anti-nuclear movement in Japan. The rather fragmented movement could never learn to coordinate and to build networks and institutionalized structures to directly influence governmental decision making processes (Feldhoff, 2014, 91). For Japan's governing apparatus, the peaceful atom is also the entrance hall to keep the option to build a nuclear bomb. A nuclear phase-out would leave Japan with a large amount of plutonium, able to build a nuclear bomb, raising international questions about its future usage. A peaceful nuclear energy program is an important element of national pride and national security sending the signal to neighboring countries that Japan is able to build the bomb (Kingston, 2014, 117), a message that seems to be important from a domestic point of view.

Nakata also mentions that risk communication to the public is not regarded as meaningful by authorities and nuclear decision makers. The decision makers are convinced that they have the necessary expertise and knowledge to make the best decision. The authorities are furthermore convinced that the public cannot judge nuclear risks properly, hence, by avoiding to spread information about nuclear risks, and by avoiding to start a dialog among all involved actors, the authorities help to prevent unnecessary anxieties among the public (Nakata, 2011, 113). The strategy to keep secrecy might have been developed for good reasons. One reason of fear and anxieties could be related to the fact that Japan lies on the Circum-Pacific earthquake zone and the Japanese Archipelago is one of the most active seismological areas in the world (Nakata, 2011, 103). The risk assessment of nuclear power plants in that seismological active areas can never exclude the risk of major natural disasters, such as earthquakes for any nuclear power plant in Japan.

Japan's civil society is an active element of communal life where neighborhood associations play an important role in organizing the municipal life and interact with the local government and household matters, such as organizing recycling (Ogawa, 2014, 52). The anti-nuclear movement in Japan is mostly linked to the peace movement and activist groups that emerged in the aftermath of Hiroshima, Nagasaki, and nuclear tests in the Pacific. According to Ogawa, the strongest emergence of that movement was in the 1960s and 1970s. In the 21st century, political movements in Japan are not a social phenomenon across the population, but rather supported by people with uncertain employment status, retired people, and freelancers. Before the nuclear accident in Fukushima Daiichi in 2011, there were no major protests against nuclear power plants beside 'not in my backyard' (NIMBY) protests of local interest groups, such as fishermen, concerned by the construction of a nuclear power plant on the coastline. As a consequence, even in the 1990s, new nuclear power plants were built without facing social resistance. The issue of nuclear energy in Japan was a topic that was not discussed widely in the public: "[u]ntil the recent nuclear crisis, honestly speaking, I observed that ordinary people in Japan, including myself, were not saying much about the country's nuclear energy policy" (Ogawa, 2014, 59). After the Fukushima accident the anti-nuclear movement found support in the population to gather for large protests in 2011 and 2012. The protests after the Fukushima accident and the history of the anti-nuclear peace movement in Japan demonstrate that a critical mass of public can be mobilized. For Japan the question is, from Okawa's point of view, whether these movements can contribute to long-term political changes in Japan's political system (Ogawa, 2014, 61). Aside from the huge public protests after the Fukushima disaster (the most massive protest since the 1960s, (Kingston, 2014)) the event did not change the country's energy policy.

One reason for authorities' ignorance of public demands is the close link between all participants that have been involved in Japan's nuclear project. This alliance of pro-nuclear actors is called the "nuclear village" (Kingston, 2014), a conglomerate of major public institutions and interest groups. Kingston (2014, 108) summarizes the nuclear villages as: "The "nuclear village" is the term commonly used in Japan to refer to the institutional and individual pro-nuclear advocates in the utilities, the nuclear industry, the bureaucracy, the Diet (Japan's parliament), business federations, the media, and academia." This network of interests is based upon cooperation and reciprocity offering power and resources to those actors who share the same interests. The 'village', having a huge advertisement budget, also massively influenced how media presented the topic of nuclear energy to the public. As a result, journalists continuously downplayed the consequences of domestic nuclear accidents prior and after the Fukushima Daiichi accident.

Different investigations after the Fukushima accident revealed that Japan's nuclear energy sectors lack a culture of safety that is due to the close relationship between regulators and the utilities, with regulating agencies regulating in the interests of the utilities. The tight connections resulted, for example, in downplaying the possibility of a tsunami accident for nuclear utilities and denying to implement international nuclear safety standards before 2011 (Kingston, 2014, 107). According to Kingston, the nuclear village is powerful, resilient, and able to establish a pro-nuclear government and by avoiding a energy policy that aims for a nuclear phase out fully able to ignore anti-nuclear concerns and protests within the society (Kingston, 2014, 109). The closed political opportunity structures in Japan, as well as public's moral guilt of blaming authorities, does not allow civil society actors to establish and to institutionalize nation wide and long lasting opposition against nuclear power. It remains an open question as to whether the Fukushima Daiichi accident changed anything permanently in Japan's nuclear strategy.

6.2.6. Summary of historical overview

This chapter of my dissertation so far introduced the development of nuclear energy from the point of view of American elites and summarizes the nuclear development and the social reactions within five countries since the atom entered the public sphere. It is an ad-hock summary with its limitations. By letting Alvin Weinberg and Dwight Eisenhower express their thoughts, I wanted to take the reader back into the very first enthusiastic era of nuclear power: the euphoric idea of the atom of peace, the twin-sister of the atomic bomb, as means for prosperity and growth for humanity. Nuclear technology was birthed by a gigantic military, scientific, and industrial complex called the Manhattan Project in 1942. In the historical review, I showed how the nuclear project has been developed in the U.S., Great Britain, France, Germany, and Japan (see also Table 1).

Table 1: Summary of key aspects of nuclear energy development

	United States	**Great Britain**	**France**	**Germany**	**Japan**
Nuclear project	Rapid development till 1974; state authorities only indirectly influenced development.	Moderate development; centralized authorities promoted development.	Rapid development since 1974; centralized authorities promoted and controlled development.	Moderate development; industry and state authorities promoted development.	Rapid development since 1974; centralized authorities and private companies promoted and controlled development.
Anti-nuclear movement	Well connected anti-nuclear movement; success of local groups.	Well connected but weak anti-nuclear movement through all levels of society; disarmament protests; weak influence on policies.	Strong movement but groups failed to institutionalize a strong anti-nuclear movement; marginalized success of local groups.	Well connected anti-nuclear movement; green movement and consolidated green party; successfully reached a nuclear phase-out bills.	Marginalized anti-nuclear movement; almost no protest against nuclear sites; revival of protest culture after Fukushima accident.
Nuclear project's future	Very moderate development of nuclear project.	Pursuing the nuclear project with foreign partners.	Continuous development of nuclear project.	Stop of nuclear project.	Stop of nuclear project after Fukushima; strong efforts to gain back pre-Fukushima status quo.
Opportunity structure	Inclusive system; high opportunity for opposition.	Exclusive system, low opportunity for opposition.	Exclusive system; low opportunity for opposition.	Exclusive system; high opportunity for opposition.	Exclusive system; low opportunity for opposition.

I have summarized how an authoritarian apparatus developed the idea of nuclear technology, realized it and defended the technology against public opposition. I also pointed out that not all countries are able to build the institutional conditions to make nuclear a dominant source of electrical energy in the country on the one hand, and to build trust in society, or to suppress distrust, to make the public believe in the benefits of nuclear energy on the other. In the U.S. and in Great Britain, the development of nuclear power came to an temporary standstill with new power plants under construction. In Germany the technology has been more or less abandoned. In Japan, an external event led to a shut down of all nuclear power plants, but it is questionable if the shut down will be permanent. Given the possibility of future natural disasters in Japan, bringing nuclear technology back to life on a dragon's tail can add more risk to Japanese's society in the future. France is an example of how nuclear technology became the monopoly of electrical power resource. A centralized industry within a centralized state, with centralized finance, centralized universities, centralized medias, centralized police and no laws against that technology can dictate or successfully provide a technology to its citizens. Political opportunity structures, as I tried to indicate, play an important role of how civil society actors are able to develop an anti-nuclear movement able to influence political decisions to implement and develop nuclear energy. It can be shown that within a closed and exclusive system (e.g. Germany), as well as in an open and inclusive system (e.g. U.S.) an anti-nuclear movement can develop and establish itself successfully, if the political and legal system, as well as independent medias, provide opportunities to institutionalize anti-nuclear actors in the public arena (Rucht, 1990; Kitschelt, 1986; Dryzek et al., 2002).

6.3. Research overview and hypotheses

In this section I first summarize the theoretical concept of risk perception. Then, I introduce concepts for explaining differences in public nuclear risk perception, and derive hypotheses of expected relationships between nuclear risk perception and individual attributes.

Risk defined from a social science perspective "refers to uncertainty about and severity of the events and consequences (or outcomes) of an activity with respect to something that humans value" (Aven and Renn, 2009, 6; compare also Rosa, 1998, Rosa et al., 2014). The definition allows the term risk to be perceived as a situation or action that has desirable as well as undesirable outcomes. It is related to uncertainties and not to probabilities, and the consequences of the outcome are not conditioned to quantifiably outcomes. Risk, as defined here, is not understood as a technical definition of risk as the product of the probability of an outcome times its consequences ($risk = probability \times consequences$). In the technical definition of risk, consequences are usually operationalized as amounts of money or numbers of fatalities. Risks from a broader perspective are based on a human judgement about an outcome that humans value. The outcome is uncertain. According to that definition risk is a subjective evaluation of an activity, such as the evaluation of nuclear power (compare also Section 2.4). Individual's nuclear risk perception, for instance, can be evaluated by asking respondents as how dangerous they perceive nuclear power.

Risk perception research has been intensively examined in social sciences, especially in the areas of social psychology, sociology, technical risk assessment, and the topic of risk governance (for an overview see Rohrmann and Renn, 2000 Renn, 2008, see also Section 4.2). Early research on risk perception started in the 1970s when Paul Slovic and his colleagues developed the psychometric paradigm (Slovic, 1987, 2010, 2000a). These studies are characterized by respondents who are asked to judge different risk sources according to different risk characteristics. The results show that nuclear power and nuclear weapons are perceived as dreadful, uncontrollable, catastrophic and among other characters as involuntary. Nuclear risks furthermore are perceived as unknown to exposed people and expected to have delayed effects. Therefore, nuclear technology is perceived as dreadful and unknown to the population. These results challenge technical risk assessments and scientific views that perceive nuclear power as a comparably minor risk for population. The perceived gap between experts' and laypeople's risk judgements is often explained by an irrational and biased judgement of laypeople who base their judgements on heuristics (Tversky and Kahneman, 1973, 1974) and not rational reasoning. Research on the emotional aspects of risk evaluation can show that laypeople's judgement's are an interplay of an emotional and cognitive judgement – it is all but an irrational process (Finucane et al., 2000a; Peters et al., 2004; Slovic et al., 2007; Siegrist and Sütterlin, 2014).

A broader more integrative concept, the 'Social Amplification of Risk Framework' (SARF) (Kasperson et al., 1988, 2003, see also Section 4.2.8) aims to explain how an uncertain activity or event is perceived in society as a risk and how different social actors and institutions are communicating actual or hypothesized consequences of a risk event. According to this framework social actors communicate risks differently and can act as transmitting stations that either amplify or attenuate risk perception in society. Hence, it is very likely that in different societies risk perception can be more or less pronounced, depending on the media structure, the political institutions, and the connectedness of actors in the civil society. This concept, a framework rather than a theory, also provides an explanation for why sudden events, such as major nuclear accidents, e.g. in Three Mile Island, Chernobyl, or Fukushima, are able to spread across social boundaries and are able to affect distant communities, industries, or countries (Slovic et al., 1984, 1991).

Research on the effect of nuclear accidents on risk perception shows that individuals who prior to an accident were indifferent about the risk of nuclear power are more likely to turn into opponents of nuclear power than people who supported nuclear power prior to the accident (Renn, 1990). A-priori beliefs are perceived as very important to judge nuclear risk after an accident (Eiser et al., 1989, 1990; Van Der Pligt and Midden, 1990; Brede, 1990, see also Section 5.5). An a-priori negative image of nuclear power will be confirmed by additional negative incidents, people in favor of nuclear energy hold both positive and negative images of nuclear power. Hence, individuals holding negative images are more likely to change their evaluation of the technology towards a more skeptical perception (Siegrist and Visschers, 2013; Visschers and Siegrist, 2013, Section 4.2.7). It is assumed that in the short run, accidents can change nuclear risk perception dramatically, depending on the level of trust in the risk governing institutions (Poortinga et al., 2013) and the levels of exposure to radiation (Drottz-Sjöberg and Sjöberg, 1990).

In this empirical chapter, I am not analyzing the effect of nuclear accidents on individual nuclear risk perception. I only want to emphasize that the historical experience of nuclear accidents in different societies at different time points can be an explanation for different levels of nuclear risk perception within and between societies. To test the effect of historical events, longitudinal panel data are necessary. The data I analyze for my regression analyses are cross sectional data conducted in 2010 before the nuclear accident of Fukushima Daiichi on March 11, 2011, hence, I cannot observe changes of nuclear risk perception on individual level over time.

In my analyses I focus on the relationship of nuclear risk perception and socio-demographic factors, which I assume influence individual's nuclear risk perception (compare Section 5.2, Section 5.2.3, Section 5.3). It is worth mentioning that with the given data structure I only can analyze relationships and no causal dependencies. Therefore, the causal dependencies hypothetically expressed here are assumptions based either on theoretical explanations or empirically observed evidence by previous research. For my analyses I refer to an integrative framework introduced by Renn and Rohrmann (Renn and Rohrmann, 2000b; Renn, 2008, Section 5.6) to explain the complex relationship of risk perception and individual or contextual factors shaping attitudes towards risk, in my case, towards nuclear risks. The integrative framework of risk perception is designed to integrate psychological, social, and cultural factors. These factors are nested within each other. On the personal level, cognitive and emotional factors such as heuristics or affects are assumed to be influential factors of risk perception[67]. Individuals, independent of their cognitive and emotional status are nested within social contexts and as such bearer of social attitudes and attributes. In this empirical research, I will focus mostly on factors located on that level analyzing the relationship of attributes such as gender, age, and social status, as well as on social values and attitudes. These values and attitudes are trust towards political institutions and society or attitudes towards economic prosperity in contrast to environmental safety. Renn and Rohrmann (2008, 143-144) also mention wordviews and the predominant economic and political culture, manifested in society by its social institutions. In their integrative framework, this level of cultural factors is the last level that provides explanatory factors to explain individual's risk perception. I address this level by testing for individual versus collectivistic worldviews, as introduced by cultural theorists.

[67] In my second empirical chapter, analyzing the effect of the unexpected event of the Fukushima Daiichi nuclear accident on nuclear risk perception I will explain the expected relationship of heuristics and of affects on risk perception in more detail (compare Section 7.2.1).

One widely discussed socio-demographic aspect of nuclear risk perception is the assumed and observable difference of risk perception between women and men. One explanation, based on the socialization process of individuals within a Western nucleus family, assumes that men take the role of the breadwinner and provider, whereas women are the caretaker and, compared to men, identify themselves more with the community and social environment (Chodorow, 1978). According to this explanation, it can be assumed that men are more concerned about the economic wellbeing of their family whereas women are more concerned about the health and safety issues for the family and community. Men from that point of view perceive nuclear risks as a beneficial technical issue, able to control, whereas women see nuclear as a constant threat for safety and health. Davidson and Freudenburg (1996) question the direct effect of the socialization process on risk perception because through social changes the role models between women and men are not clearly to be separated. Both women and men are bread winners and caretakers. At the same time, it is still possible that traditional role perceptions shape individual's interests, educational or occupational decisions and, hence, indirectly influence attitudes towards technological risks. Empirical studies clearly indicate that women perceive health and safety issues as more threatening than men and create a strong awareness of risks that are a potential threat for their family and community (e.g., Brody, 1984; Solomon et al., 1989; Greenberg and Schneider, 1995; Forbes and Sells, 1997). I assume that women, compared to men, express higher levels of risk perception. This effect should be more pronounced in social subgroups where the traditional masculine role model is still promoted, with men expressing significant lower levels of nuclear risk perception.

Hypothesis 1: Women, compare to men express higher levels of nuclear risk perception.

Hypothesis 2: Generally speaking the assumed positive effect for women is more pronounced within certain social contextes.

An other aspect in evaluating risks is the perceived knowledge about a risk. It is assumed that people who have more knowledge about a potential risk express lower concerns. Lower concerns, from this point of view, evolve because an individual's judgement is based on rational evaluation of the likelihood of an event and its consequences and less based on intuitive heuristics and irrational feelings (Kuklinski et al., 1982; Lopes, 1991). Davidson and Freudenburg (1996, 317), in their review on empirical studies, show that in some studies men express more knowledge about a risk's technical details. The authors, furthermore show, that empirical studies among female and male experts on different risk sources reject the 'knowledge support hypothesis.' In this studies, women, with same levels of education, express higher levels of risk concern compared to their male counterparts. It is also the case that the assumed effect is reversed, resulting in higher risk perception among better informed individuals. Hence, knowledge is assumed to be related to broader values and identities, related to the concept of traditional masculinity, social control, and embeddedness within a social community (Kuklinski et al., 1982; Costa-Font et al., 2008; Reardon and Govender, 2013; Kahan et al., 2007). For my research, I assume that perceived knowledge indirectly shapes risk perception through social status (compare Section 5.3.5). On one hand knowledge can create higher levels of self-confidence and, hence, ignorance resulting in a perceived irrational judgement among the public. Therefore, people who assume that environmental problems are exaggerated should also express less risk perception on nuclear power. On the other hand, the social reproduction of knowledge through the institutionalized education system in each society should reproduce its elite structures that supports nuclear power. I therefore assume that more educated people perceive themselves as more knowledgeable and should express lower risk concerns. This effect should be less pronounced among women because, for example due to socialization, women are less likely to study technical or economic issues.

Hypothesis 3: People expressing more knowledge about a risk should have lower nuclear risk perception.

Hypothesis 4: Better educated people express lower levels of nuclear risk perception.

Hypothesis 5: The negative effect of education should be less pronounced for women.

Risk perception is also assumed to be negatively related to trust in political institutions (compare Section 5.2.3). Individuals who express more trust in political institutions are assumed to be less likely to express higher levels of risk concerns (Freudenburg, 1993; Flynn et al., 1992; Fox and Firebaugh, 1992; Slovic, 1999; Bella, 1987; Slovic, 1993; Rayner and Cantor, 1987; Viklund, 2003). Today, trust in the community and in public institutions is an important factor because risks are mostly indirectly perceived through media or taught in schools or universities. The information building process is not based on direct experience, but on indirect processes, amplified or attenuated by communication processes in an individual's social networks (Löfstedt, 2005, 2003; Breakwell, 2007). The negative effect of trust is expected to vary among different countries because since the 1960s trust in public authorities is declining to different degrees within Western societies (Siegrist and Cvetkovich, 2000; Siegrist et al., 2000).

Hypothesis 6: People who express higher levels of trust in governmental institutions are more likely to express lower levels of nuclear risk perception.

A further aspect negatively related to risk perception is concern of economic development in the future. It is assumed that individuals who express higher economic concerns are more likely to express lower levels of nuclear risk perception (Stout-Wiegand and Trent, 1983). Economic prosperity is a materialistic value according to Inglehart (1997; 1988) and nuclear power is a symbol of economic growth and a landmark of technical and materialistic merits of modernity. Beside the value explanation perspective, the economic growth assumption is furthermore linked to the occupational status of a person, assuming that people, independent of their sex, who are part of the labour force are more likely to be concerned of economical issues (Davidson and Freudenburg, 1996). Empirical studies cannot confirm the later assumption. A study by Mohai (1992) shows that, on average, full-time employed women express higher levels of environmental concern compared to full-time employed men. A study by Blocker and Eckberg (1989) rejects the assumed negative relation of employment status and risk perception by finding that employed people, independent of their sex, on average express higher levels of concerns.

Hypothesis 7: People concerned about the economic development express lower levels of nuclear risk perception.

Hypothesis 8: Full time employed people express higher levels of nuclear risk perception.

Hypothesis 9: Full time employed men express lower levels of risk perception compared to women.

According to Boholm (1998) and also Flynn and colleagues (1994) the fixation on a value system that is based on traditional values, status, power, inequality, and materialistic idealism, such as endless economic growth, is fundamentally expressed in a specific male subgroup of population. Empirical studies can show that, for example in the U.S., men on average, who are better educated, with higher income, politically conservative oriented, and white express very low levels of risk perception, compared to other subgroups (see also Finucane et al., 2000b; McCright and Dunlap, 2011). The assumed relationship of attitudes in favor of economic growth resulting in lower risk perception can therefore not be rejected for specific subgroups within society. I therefore assume that higher socio-economic status, operationalized by respondent's educational degree and income, influence risk perception significantly (see Hypothesis 3). This effect, due to socialization, should be more pronounced among men than women. A French study by Bastide (1989) also reveals that better educated and richer people are more likely to underestimate the negative consequences of different risks, whereas less educated poorer people overestimated a risk's negative consequences. The feelings of insecurity and hopelessness, the authors assume, leads to a status-induced gap between rich and poor people. Nuclear power, can be perceived as a technical and solvable problem among people with higher status, whereas it is perceived as a threat for safety among people with lower status.

Hypothesis 10: Higher social status, measured through income and education, results in lower nuclear risk perception.

In risk perception research, age is also assumed to be an influential factor on individual's evaluation of technical risks as well as environmental problems. From a cultural theory's point of view, older people tend to have more traditional values and develop an hierarchical bias, resulting in lower risk perception (Grendstad and Selle, 2000; Peters and Slovic, 1996; George and Southwell, 1986). Younger people are less integrated in the existing political and economical structures and are more in favor of pro-environmental reforms and social changes (Van Liere and Dunlap, 1980; Malkis and Grasmick, 1977).

Older people, being better integrated in society, are assumed trying to maintain order and are more interested in keeping the existing economical and social structures (Carstensen et al., 1999). All of these explanations assume a negative relationship between risk perception and age. Research on the willingness to pay in order to solve environmental problems reveals that the highest support for environmental problems is among people in the age group around 40 years, with a decline in willingness to pay for older respondents. This research also shows that due to different time discounting factors future-oriented goals are more discussed among younger generations, hence, resulting in a higher awareness of long-term threats to society among younger people (Dockins et al., 2002; Wiernik et al., 2013). In contrast to the assumed negative relationship, there are also studies that reveal a positive relationship, arguing that older people, being more experienced are taking greater care of their social environment and live a less energy demanding lifestyle (Morris and Venkatesh, 2000; Smola and Sutton, 2002). Following the traditional value explanation, I assume a negative relationship between age and nuclear risk perception.

Hypothesis 11: Age is assumed to negatively influence nuclear risk perception.

Political ideology is assumed to be highly correlated with nuclear risk perception and environmental attitudes (Eiser et al., 1990; Flynn et al., 1994). It is assumed that people who hold a conservative political ideology hold values based on hierarchy, order, stability, and conformity and are against changes in society that are able to challenge the existing political and ideological mindset. According to that view, pro-environmental reforms and more regulation on hazardous technologies are threatening the existing political and economical structure of a society (Dunlap, 1975; Van Liere and Dunlap, 1980). A gap between left-liberal and right-conservative political ideologies should be observable within societies, with more left-liberal people expressing higher awareness of environmental risks, especially nuclear risk perception (Dietz et al., 1998; Jost et al., 2008).

Hypothesis 12: Compared to conservative people, people with a left political orientation are more concerned about nuclear power's dangerous consequences.

I also include a person's location, the place they live, into my analysis because in literature of risk perception it is agued that respondents who live in urban or rural areas evaluate environmental risks differently. Van Liere and Dunlap (1980) assume that people living in urban areas express higher levels of environmental concerns. The authors argue that people who live in a city are more likely to be exposed to direct environmental problems, such as air pollution. It is furthermore assumed that people living in rural areas perceive nature as a resource to be exploited, especially in small towns that try to compete with other rural areas to attract business development or want to provide employment opportunities for its inhabitants. This assumed positive relationship is challenged by contradictory results in studies that cannot prove a clear relationship, revealing that risk evaluation depends on the specific economical structure in the area and on the specific risk that is analyzed (Freudenburg and Jones, 1991; Hamilton et al., 2013; Bastide et al., 1989; Olofsson and Öhman, 2006). Alternatively, people living in rural areas can develop strong nuclear risk perception and opposition (NIMBI, 'not in my backyard', phenomenon) if their community is affected by future nuclear power plant developments or nuclear waste disposals (Keller et al., 2011; Gattig and Hendrickx, 2007).

Hypothesis 13: The relationship of location, the place someone lives, especially rural areas, and nuclear risk perception remains unclear. Both arguments to exploit and protect a community's natural resources argue for and against higher or lower levels of nuclear risk perception compared to citizens living in urban areas.

According to cultural theory (Thompson, 1980; Douglas and Wildavsky, 1983; Thompson et al., 1990, see also Section 5.2) social context shapes an individual's value structure influencing how people evaluate risks. Individuals base their risk judgement according to their cultural lens. According to proponents of cultural theory, cultural prototypes can be identified each of which is characterized by a different risk portfolio. More individual people are assumed to be risk takers and less concerned about facing risks and solving risks, within their fields of personal interests. More collectivistic people are perceived to be less risk prone, perceive outside risks also as more dangerous and try to avoid them, or want them to be managed by superior authorities such as religious powers or state institutions. I test this assumption by including a variable that is asking for respondent's individualistic or collectivistic worldview.

Hypothesis 14: Nuclear risk perception is assumed to be higher among people holding more collectivistic worldviews.

I summarize the assumed relationship between social factors and nuclear risk perception in Table 2.

I assume that the above discussed relationships between social factors and nuclear risk perception (compare Table 2) do not differ across the five countries in my analysis. The U.S., Great Britain, France, Germany, and Japan all developed their peaceful or/and military nuclear program soon after World War II, having successfully connected nuclear power plants to grid in the late 1950s and early 1960s, before the energy crisis in 1974. All of the countries experienced high levels of economic growth and are part of the major advanced economies on this planet. In all countries, civil movements have been active, with a history of different protests in various forms against nuclear weapons and nuclear power. I think that this movement is less developed in Japan, only supported by subgroups in contrast to, for example Germany, a country in witch the anti-nuclear movement is widely supported within all parts of society. In Germany, I therefore assume that nuclear risk perception is more homogeneous distributed among population subgroups. In the U.S., France, and Great Britain I expect to observe clearer differences within the societies, indicating more pronounced differences between subgroups who perceive nuclear energy as more dangerous and subgroups in society that perceive nuclear

Table 2: Assumed relationship of individual social factors and nuclear risk perception.

Hypothesis	Factor	assumed effect
Hypothesis 1:	female	+
Hypothesis 2:	interaction of social context and female	+
Hypothesis 3:	knowledge	−
Hypothesis 4:	education	−
Hypothesis 5:	interaction education/female	+
Hypothesis 6:	trust in government	−
Hypothesis 7:	economic value	−
Hypothesis 8:	occupation	−
Hypothesis 9:	interaction occupation/female	+
Hypothesis 10:	social status (income/education)	−
Hypothesis 11:	age	−
Hypothesis 12:	left political orientation	+
Hypothesis 13:	place of living (rural area)	+/−
Hypothesis 14:	collectivistic worldview (collectivistic)	+

power as less dangerous. This gap should be observable among different social classes and age groups. Within all countries, a difference should be observed between women and men, assuming female respondents expressing higher concerns for nuclear risk perception compared to male respondents.

6.4. Data, methods, and operationalization of variables

To analyze the above discussed relationship between nuclear risk perception and socio-demographic factors, social values, and beliefs, I use a dataset provided by the International Social Survey Programme (ISSP) in 2010 (ISSP, 2012)[68]. The ISSP[69] is an international consortium of national member institutes that conduct every year a survey on varying topics in social sciences. In 2010, 2000, and 1993 the topics were on the environment. The number of member states varies across time as well as a proportion of survey questions is allowed to be changed between different waves, making it difficult to compare specific questions overt time and across countries. In the case of nuclear risk perception, differences in the data structure do not allow for complex analyses across different time points and between many countries. Therefore, I focus on a cross section design in 2010, performing multiple regression analysis for each country. Each national survey of the ISSP claims to be a representative samples of the population, conducted either in personal face-to-face (CAPI, PAPI) interviews or with self reported questionnaires sent to the respondents. The time points or periods of fieldwork differ for each

[68] The data are available for non-commercial purposes via `http://www.gesis.org/en/issp/home/` (accessed November 15, 2015).

[69] In 2015 there are 45 member states according to the ISSP website (`http://www.issp.org/`, (accessed November 15, 2015)).

country. Some countries, such as Germany or Switzerland, conduct two ISSP questionnaires every second year, covering two topics at the same time. For the ISSP 2010 on environment, this means that some national member institutes conducted the questionnaire in 2010 and some in 2011. For my analyses I choose five countries whose data were conducted in 2010. The countries I have chosen for my analyses are the United States (conducted: 18. March 2010 - 14. August 2010), Great Britain (conducted: 11. June 2010 – 13. November 2010), France (conducted: 01. September 2010 – 31. December 2010), Germany (conducted: 31. May 2010 – 30. October 2010), and Japan (conducted: 27. November 2010 – 05. December 2010).

The dependent variable *'nuclear risk perception'* is operationalized in the ISSP as an ordinally scaled variable. Respondents are asked to evaluate whether they *'think that nuclear power stations are...'* (1) *'extremely dangerous for the environment,'* (2) *'very dangerous,'* (3) *'somewhat dangerous,'* (4) *'not very dangerous,'* (5) *'or, not dangerous at all for the environment.'* For the purpose of my analyses, I create a binary variable combining the first two categories to express that respondents perceive nuclear power as *'very or extremely dangerous'* for the environment. The reference category is people who perceive nuclear power as somewhat or less dangerous. I am interested in this analysis of the subgroup of people who perceive nuclear power as at least very dangerous compared to a more indifferent or almost not concerned group of people. I am interested which factors increase or diminish the likelihood to perceive nuclear power as very/or extremely dangerous. Assuming a causal relationship, I am aware that with the given data structure I test for relational and not a causal relationship of dependent and independent variables in the model. To analyze the relationship of the binary coded dependent variable and various independent variables, I use multiple logistic regression analysis, using `stata` software (version 13). I receive average marginal effects or predicted changes by using the stata ados `margins`, `marginsplot` (Williams, 2012), and `estout` (Jann, 2014; Jann and Long, 2010; Jann, 2007).

The independent variables are operationalized as categorical dummy variables with one category as reference category. *Gender* is binary coded with male as reference category. *Age* is recoded in age groups of 15 years with people age 15–29 as reference category[70] and the oldest category ranging from 75–90. *Urbanization* defines people living in urban areas as reference category and people living in a 'Town or small city' and a 'Country village' as separate categories. *Education* is a variable with five categories, with the lowest category 'Now or lowest degree.' The other categories are 'Intermediate secondary complete,' 'Secondary complete/ University incomplete,' and 'University degree complete.' A household's *income* is recoded in three categories, 'lower', 'middle' and 'upper' tercile, based on the income distribution per country, with the lowest tercile as reference category. *Occupational status* is a variables with three categories: people who are 'not in paid work' are the reference category. People 'working less than 40 hours per week' and people 'working 40 hours or more per week' are the two other categories. *Political ideology* has three categories with the reference category of people

[70] In most countries the minimum age is 18.

who express to 'see themselves in the center or have no preference or do not vote'. In contrast to that people who see themselves 'left from the center' are one category and people who see themselves ideologically 'right from the center' are the third category. I included two trust variables (*trust in government* and *trust in people*) with both times as reference category people who have 'no preference'. The other two categories of each variable are people who either 'trust the government' or 'distrust the government' and 'trust other people' or 'distrust other people'. Trust in people is included in the model to test whether general trust differs from institutional trust. I include two variables that test whether people prefer economic growth rather than environmental development. The first variable *environment* asks if people agree (on a five point Likert skale) to the statement: 'We worry too much about the future of the environment and not enough about prices and jobs today.' People who do not agree to that statement are the reference category: 'worry not too much'. The second question *economic growth* asks respondents whether they agree that 'In order to protect the environment [COUNTRY] needs economic growth.' This binary variable also has people who do not agree to that statement as reference category. To test whether more knowledgeable people perceive nuclear power as less dangerous, I included two binary coded items. The *knowledge exaggerated* variable has people as reference category who disagree or are indifferent to the statement that environmental threats are exaggerated. People who express that they do not know much about the causes of environmental problems are coded as the reference category for the variable *knowledge causes*. The final question is integrated in the model as the attempt to integrate a value question into the model that captures individuals who perceive themselves as more individualistic or more collectivistic.[71] People who agree to the statement: 'There is no point in doing what I can for the environment unless others do the same', are perceived as collectivistic individuals. People who disagree are perceived as individualists and are the reference category for the variable *collectivism*.

For each country, I run four separate models integrating stepwise additional theoretical blocks into the model: After (1) testing the effect of gender, age, and degree of urbanization, I (2) test for the effect of social status: education, income, and occupation. I then (3) test for the trust variables and party affiliation. In the final model (4) I include value variables. To test for interaction effects on gender and education and gender and occupational status, I run a separate model with interaction effects and describe the results in the text and show separate figures in some cases if the results seem to be of importance to understand the nonlinear nature of interacting social factors.

[71] I am aware that this question could also be associated within the field of social dilemma and collective actions theories, a subject I do not mention in my dissertation.

6.5. Results

6.5.1. Risk perception: overall distribution

In the first part of my empirical analyses I describe the overall distribution of nuclear risk perception in each country at different time points (compare Table 3). For Germany and Japan, for all three time points (1993, 2000, 2010) data from the ISSP are available. For the United States and Great Britain data from 2000 and 2010 are available; for France data for 2010 are available. Because of the given data, structuring a comprehensive comparison of overall risk perception over time and across countries is not possible. Yet, the available data still provide enough information to compare the over all level of nuclear risk perception in 2010 for all five countries. Furthermore, by referring to previous time points in 2000 or 1993 (or both) it is possible to see whether the distribution in 2010 shows a pattern that has been observed in the past or is following a specific trend. For this analyses, the nuclear risk perception variable with originally five categories is recoded in a three point Likert scale.[72]

The results show that the majority of respondents in Germany perceive nuclear as 'very dangerous' (70 % in 2010). The proportion of people who perceive nuclear power plants as 'not (very) dangerous' is stable over time. It seems that since 2000, the proportion of people who perceive nuclear as 'somewhat dangerous' changed their attitudes towards nuclear power, perceiving nuclear as more dangerous (30 % in 2000 compared to 19 % in 2010). This is only an assumption because cross-sectional data do not allow to control for changes on the individual level. Results in Japan show a different development of attitudes over time. A majority of respondents perceived nuclear power as very dangerous in the ISSP waves of 1993 and 2000 (54 % in 1993 and 58 % in 2000). Risk perception dropped to 39 % in 2010. At the same time, the low proportion of respondents who perceived nuclear as 'not (very) dangerous' rose from 12 % in 1993 to 22 % in 2010. According to the observed levels of risk perception in Japan prior to the Fukushima Daiichi accident the population seemed to be proportionally less concerned compared to previous waves. The middle category of a proportion of one third of all respondents is comparably stable over time and in the range of the proportion observable in the U.S., Great Britain, and France. Japan in that sense is not an outlier in terms of people who chose to answer the middle category.[73] Nuclear risk perception in the United States in 2010 compared to 1993 levels does not indicate major changes. The largest group of respondents perceives nuclear power as very dangerous: 44 % in 1993 and 46 % in 2010. In Great Britain for 1993 and 2010 there is a decline in nuclear risk

[72] The variable nuclear risk perception was conducted with the same wording and categories over all three time points. The answer categories 'extremely dangerous' and 'very dangerous' are recoded in the category 'very dangerous'; the answer category 'somewhat dangerous' is kept; the answer categories 'not very dangerous' and 'not at all dangerous' are recoded into one category 'not (very) dangerous.'

[73] Some studies mark that people in Asia tend to avoid to chose extreme answer categories, leading to response biases (compare for example Franzen and Vogl, 2011).

Table 3: Proportion of nuclear risk perception per country over time.

Country	Nuclear power is ...	1993	2000	2010
Germany				
	very dangerous	65 %	57 %	70 %
	somewhat dangerous	24 %	30 %	19 %
	not (very) dangerous	11 %	13 %	11 %
	$N =$	2,021	1,416	1,317
Japan				
	very dangerous	54 %	58 %	39 %
	somewhat dangerous	34 %	33 %	39 %
	not (very) dangerous	12 %	9 %	22 %
	$N =$	1,242	1,119	1,201
United States				
	very dangerous	44 %		46 %
	somewhat dangerous	39 %		33 %
	not (very) dangerous	17 %		21 %
	$N =$	1,403		1,331
Great Britain				
	very dangerous	48 %		39 %
	somewhat dangerous	37 %		35 %
	not (very) dangerous	15 %		26 %
	$N =$	1,188		852
France				
	very dangerous			41 %
	somewhat dangerous			32 %
	not (very) dangerous			27 %
	$N =$			2,148

Source: ISSP 1993, 2000, 2010 (own analysis)

perception of 9 %-points (48 % to 39 %) and an increase in people who perceive nuclear as ‘not (very) dangerous’ of 11 %-points (15 % to 26 %). Though the difference to British respondents’ is only 1 %-point, French respondents report for 2010 the highest proportion of respondents (27 %) who perceive nuclear energy as ‘not (very) dangerous.’

The distribution of nuclear risk perception, as measured in the ISSP, in France, Great Britain, Japan, and the United States is rather similar. The only country that shows a clear positive trend in nuclear risk perception over time is in Germany. In the United States, the two time points indicate that nuclear risk perception is on constant levels. The 2010 data for Japan and Great Britain indicate that, compared to 1993 in Great Britain or 2000 in Japan, prior to the Fukushima Daiichi accident nuclear risk perception was declining with less people perceiving nuclear power as ‘very dangerous’ and more people perceiving nuclear power as ‘not (very) dangerous.’

6.5.2. Regression analysis

After the above discussed differences in nuclear risk perception between the five selected countries I want to examine whether there are observable differences on the individual level that can be used to explain how nuclear risk perception varies within and between societies. I am interested if, on the individual level subgroups differ across countries on how dangerous they perceive nuclear energy. A summary of the results is shown in Table 4. The detailed Table 5 of the full regression models (Model 4 of each country's regression analysis) can be find in Section 6.5.3, summarizing the results of each country. A detailed regression table for each country, stepwise integrating theoretical parts in the full model (Model 1 to Model 4), can be found in the Appendix (Section 6.7) of this empirical chapter.

Table 4: Summary of results across all countries

	US	GB	FR	GER	JP
Female	+	+	+	+	+
Age	−	−	−		
Urbanity		+			
Education	−	+	−	−	
interaction: education/female	+				
Income	−		−		
Occupation			−		
Interaction: occupation/female					
Party (left)	+			+	+
Trust (government)			−	++*	
Trust (people)	−	−		+	
Environment (worry too much)					
Economic growth			−	−	
Knowledge: no threat	−	−	−	−	
Worldviews					

Source: ISSP 2010 (own analysis);

significant effects for dark colored cells with + or − symbol;

positive (green) or negative (red) tendency in colored cells;

*: lower risk perception for indifferent people (in Germany).

United States of America

In the United States, female respondents are more likely to express higher nuclear risk perception than male respondents. Results of Model 1 also indicate that people in older cohorts of age 45 and older are more likely to perceive nuclear risk as not dangerous or somewhat dangerous. The age effect for people of age 60 or older remains significant negative when for social status variables is controlled for (Model 2). People with the highest educational degree are 21.9 % points less likely to express higher nuclear risk perception than people with the lowest level of education. Also people, living in households that belong to the highest income group, the third tercile, are also less likely to perceive nuclear as very dangerous or extremely dangerous. All of the effects discussed remain significant and do not change much in their magnitude when party affiliation and trust variables are controlled for (Model 3). Respondents who have a left-liberal or democratic party affiliation are more likely to express high nuclear risk perception than peoples who see themselves in the center or as republicans on the political right. People who express high levels of trust in other people are less likely to express high levels of nuclear risk perception (-8.4 % points) than people who do not trust much or are indifferent. Trust in government shows no significant relationship. When controlling, in addition, for values (Model 4), opinions about economic growth and ecological development in the U.S. as well as for a collectivistic or individualistic orientation do not show significant differences. Only people who believe that environmental problems are exaggerated are significantly less likely to express higher nuclear risk concerns.

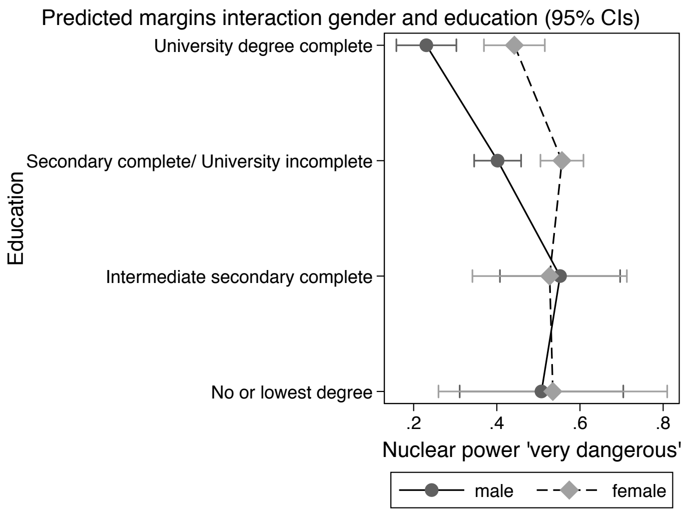


Figure 11: Average marginal effects of education by gender for the U.S.

To test whether the negative effect of education is the same for male and female respondents an interaction analysis is performed. The results, shown in Figure 11, indicate that the predicted effects vary between genders. Only with highly educated people is there a significant higher risk perception between female and male respondent. For example, women who completed university are 21 % points (predicted margins are 44 % for female, and 23 % for male) more likely to perceive nuclear energy as very or extremely dangerous compared to their male fellows who graduate from university or college. The overall tendency to express lower risk perception with higher educational degrees is observable for both genders. The negative differences are only significant for male respondents and not for women. Male respondents graduating from university significantly express lower risk perception compared to male respondents with lower educational degrees. The interaction effect indicates that in this sample the negative effect of education, especially for people holding highest educational degrees, is only perceivable among male respondents. The above discussed gender gap is not observable among lower educated people in the U.S.

A second analysis on the effect of occupational status among the sample in the U.S. reveals that the gender gap is not observable among part time employed (people who are working less than 40 hours per week) men and women.

Great Britain

The logistic regression results and the derived marginal effects for Great Britain show that there is a gender gap in nuclear risk perception with women being significantly more likely to perceive nuclear energy as very or extremely dangerous for the environment. In Model 1 the likelihood for women to express higher nuclear risk perception is 16.5 % points higher than for men. In the full Model 4 this effect is still 12.9 % points higher. Model 1 to Model 4 show that older people between 45 and 75 are significantly less likely to express higher risk perception than younger age groups or respondents 75 years and older. For me the results of the categorical age structure could indicate an U-shaped effect of age. In the sample, it is also the case that people living in a city are more likely to perceive nuclear as more dangerous compared to respondents living in a town or a small city. These results do not change when additional variables are added to the model. Comparing Model 2, Model 3, and Model 4, controlling for different theoretical blocks, changes the effect of education and income. There is a positive tendency for education with significant higher risk perception for respondents in Model 3 and Model 4. The negative effect of people whose household income is in the range of the third tercile is not significant anymore when value variables are controlled for in Model 4. Trust in people (Model 3 and Model 4) is an indicator for significantly lower likelihoods to perceive nuclear energy as very or extremely dangerous. In addition, respondents who agree that environmental problems are exaggerated are 16.4 % points less likely to perceive nuclear energy as very dangerous. Occupational status, party affiliation or trust in government, as well as values that express economic growth prone tendencies do not show significant differences from the reference category.

Separate models with interaction effects for gender and levels of education do not show different trends for female and male respondents in this sample. Both sexes are more likely to perceive nuclear as more dangerous the higher their educational degree is. There is also no significant difference between the gender effects observed for women's and men's occupational status.

France

In the French sample women, on average are more likely to express higher nuclear risk perception than comparable male respondents. There is a negative effect observable for the oldest cohorts. People 75 years of age or older are significantly different than the reference cohort of respondents younger than 30 years. Social status matters for nuclear risk perception among the French sample. People who have higher incomes and people who work full-time are less likely to express higher level of nuclear risk perception. Only in Model 4, is the negative effect of higher education levels significantly lower compared to respondents in the reference category of no or the lowest educational degree. People who trust the government or have no preference, are less likely to regard nuclear energy as very or extremely dangerous for the environment. The significant negative effect of a conservative political orientation, compared to the reference category of people who do not vote or have a preference to the center, observed in Model 3 is not significant anymore when controlled for value variables in Model 4. Separate analyses (not shown here) to test the difference between a left and right political orientation show a significant higher risk perception of people holding a left-wing political orientation, compared to respondents holding a conservative right-wing orientation. Respondents who agree that economic growth is necessary to protect the environment as well as people who express that environmental problems are exaggerated are less likely to show higher levels of nuclear risk perception.

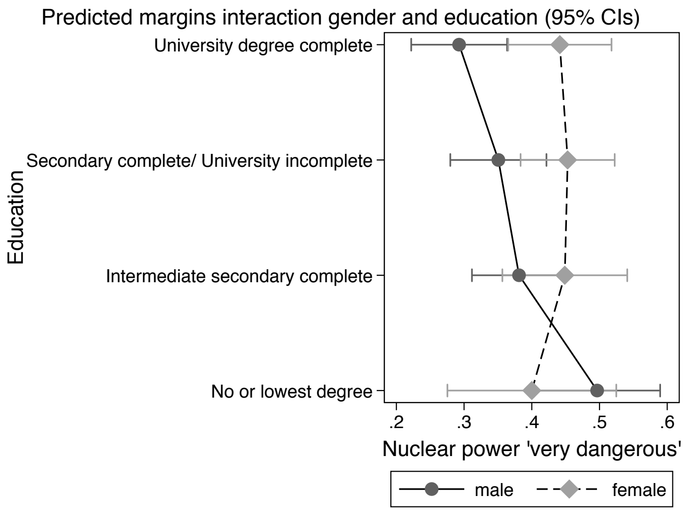


Figure 12: Marginal effects of educational level by gender for France.

Analyzing the effect of education for women and men separately (compare Figure 12) indicates that the effect for male respondents is a negative effect. Male graduating from university are on average about 20 % points less likely to express high levels of nuclear risk perception, compared to males with no or the lowest level of education.

For women, no significant differences can be observed for educational status, indicating that higher educated women have the same likelihood to express high levels of nuclear risk perception than comparable women with lower educational degrees. The observable gender gap in France is influences to some degree by highly educated men. The gender gap is not influences by the occupational status as a separate interaction analyses (not shown here) reveals. Women, as well as men in the sample are less likely to express high levels of nuclear risk perception when they are in paid work and work 40 hours or more per week, as shown in Model 4.

Germany

To analyze the German data marginal effects are computed for four models. Model 1 includes the basic socio-demographic variables gender, age, and place of living. In Model 2, the socio-demographic variables that represent specifically the socio-economic status of a respondent are included: highest degree of education, household income, and occupational status. In both model gender is the only significant effect indicating that for women there is a higher chance of about 15 % points to perceive nuclear as dangerous or very dangerous. Non of the status variables seem to influence nuclear risk perception significantly. Only when further taking into account individual's party affiliation and respondent's expressed trust in government and people respondents with the highest educational degree ('University degree') are significantly less likely (14.2 % points) to express high nuclear risk perception (Model 3). In Model 3 also people with a left political orientation and people who do not distrust other people, either trust or are indifferent, are more likely to express higher risk concerns. The significant effects of Model 3 do not change when further value questions are included in Model 4. In Model 4, people who believe that environmental development needs economic growth are significantly less likely (12.4 % points) to express high nuclear risk perception compared to people who disagree on the idea of economic growth and environmental development. Lower likelihoods of 16.8 % points are also found for respondents in Germany who belief that environmental threats are exaggerated.

Additional models controlling interactions for gender and the levels of educations, as well as for gender and the occupational status do not indicate different likelihoods for women with either higher levels of education or women with part- or full-time employment. To demonstrate the similar negative effects for women and for men the interaction effect of education is plotted in Figure 13.

Japan

Results for the Japanese sample indicate that among the socio-demographic variables, only women show significantly different likelihoods to express higher risk perception than the chosen reference categories. In Model 4, women are 8.8 % points more likely

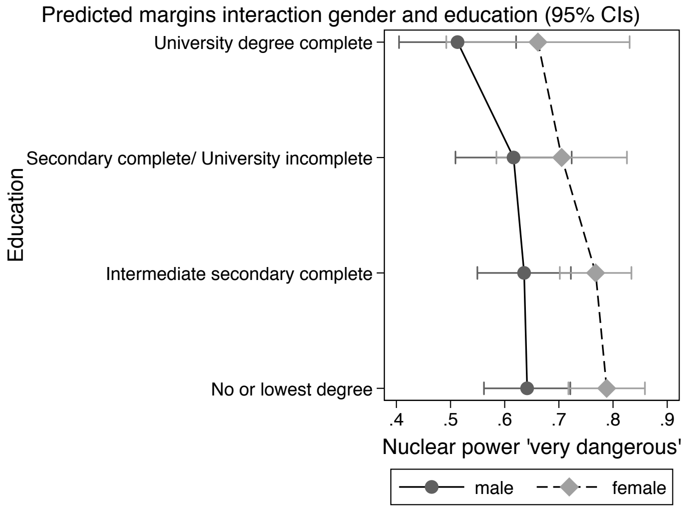


Figure 13: Marginal effects of education level by gender in Germany.

to perceive nuclear energy as very or extremely dangerous. Compared to people in the lower or upper tercile, people with a household income in the middle tercile, tend to have a higher likelihood to express a higher nuclear risk perception. This effect is not significant on the 5 % level of significance anymore in Model 4 when value variables are controlled for. Political orientation has a strong influence on nuclear risk perception. People with a left political orientation are 30.4 % points more likely to perceive nuclear as more dangerous compared to people who favor the center, the difference is even stronger compared with people holding more conservative political views. People, who neither trust or distrust other people show lower levels of nuclear risk perception; this effect, even though negative, is not significant for people expressing that they trust people. In Model 4, respondents who express more knowledge about the causes of environmental problems are more likely to be more concerned about nuclear technology than people who know less about the causes.

No significant differences can be found between both sexes regarding the positive trends in education and the negative trends in occupational status. Though not significantly different the interactions indicate for women who work full time to be more likely to be more concerned compared to women who work less than 40h a week, or are not in paid work (compare Figure 14). Men who work more have the tendency to be less likely to express higher nuclear risk perception, at least in the Japanese sample of the ISSP 2010.

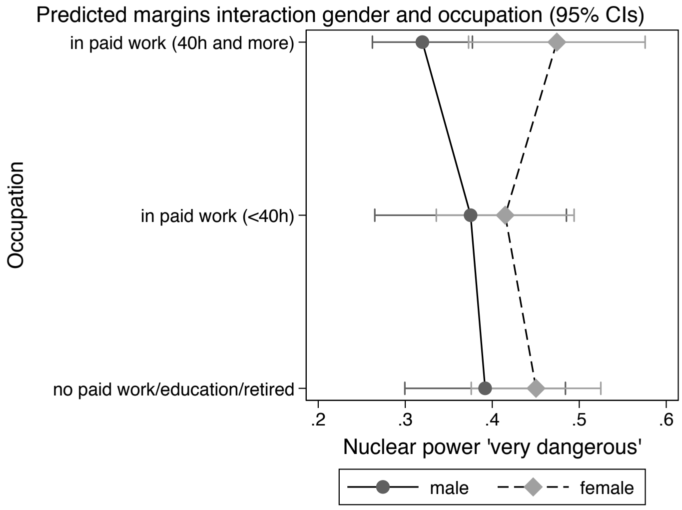


Figure 14: Average marginal effects of occupational status by gender for Japan.

6.5.3. Summary of regression analysis

Among all observed country samples and all observed models (without interaction effects) women are significantly more likely on the 5 % level of significance to perceive nuclear power as very or extremely dangerous. The analyses, as performed here, reveal a gender gap within the observed societies. For this effect and for all remaining factors compare Table 4 on page 196 and the detailed Table 5 on page 206 with the estimated effects its significant level and t-statistics.

In all five countries, older people have the tendency to be less likely to express high levels of nuclear risk perception. This negative effect of age is significantly different from the reference category in the United States, France, and Great Britain. In Germany there are no observable age effects. In Japan there could be an inverse U-shaped tendency, even though not significant, since in the sample, cohorts between 30 and 60 tend to have higher likelihoods to express higher nuclear risk perception than younger or older cohorts. To summarize the age effect I conclude that there is a negative tendency that older people perceive nuclear as less dangerous compared to younger people, especially for people older than 60 years (born before 1950). This effect is not stable across different countries, nevertheless since there is no positive tendency, especially not for the older people, I would not advise to reject the assumption of a negative age effect in future research. Whether the observed effect is an age effect or an cohort effect cannot be tested given the available data.

Location, the place people live, shows no clear tendency. Only in Great Britain, people living in cities are significantly more likely to express higher levels of nuclear risk perception. This variable seems to be a weak predictor for nuclear risk perception.

The effect of education, one aspect of the effect of social status, on nuclear risk perception does not show homogeneous results for the selected country samples. In Germany, the U.S., and France respondents with higher educational level are less likely, on average, to express higher levels of nuclear risk perception. This effect is significant for people with highest category 'University degree', compared to the reference category of 'no or lowest formal degree'. In the U.S. as well as in France this negative effect is only observable among males, when interaction analyzes for gender are performed. It is not the case that the overall negative effect of higher educational levels holds for all countries. In Japan and in Great Britain male as well as female respondents holding higher educational degrees are more likely to express higher risk perception. This positive trend is significant for Great Britain, but not in the case of Japan.

The effect of household income on nuclear risk perception, as an additional aspect of social status, shows a negative trend in all five observed countries. In the French, as well as in the U.S. sample this negative effect shows significant lower likelihoods for the upper tercile, compared with the lower tercile of the country specific income distribution of the country sample.

Occupational status, as a third indicator of social status, does not indicate an increase in the likelihood of perceiving nuclear energy as very or extremely dangerous for the environment. Only in the French sample, were people, in paid work working 40 hours per week or more, less likely to express high levels of nuclear risk perception. The French result indicates that compared to other countries the observed significant difference is a country specific phenomenon. The effect also does not vary between gender. Only in the Japanese sample, women who are in full-time paid work have the tendency to perceive nuclear power as more dangerous than men in full-time paid work.

Summarizing the effect of socio-economic status, it seems to be the case that in the U.S. and in France the assumed negative relationship between social status and nuclear risk perception is most obvious. This effect is more pronounced for male than for female respondents in the U.S. and France regarding the relationship with education. The effect, or more precise the relationship, of socio-economic status is less strong in Great Britain and in Germany. In Great Britain, education has a positive relationship, but income a negative one. In Germany, there is a negative relationship between better educated people and nuclear risk perception and no relationship regarding the household income. In the Japanese sample, there is no relationship observable between social status and nuclear risk perception. Occupational status only in France, on average, has a negative effect on risk perception. Results in Japan indicate a positive relationship for women in full-time paid work, indicating a gender gap in occupational status among full-time employed people.

The first value variable I examine is ideological party affiliation for people being non-voters or in the center compared with people waving for the more left or cheering for the more right wing dimension of a country's two-poled ideological landscape. Compared to the center/non-voter category (the reference category), in all five countries, a left ideology is related to a higher likelihood to express high levels of nuclear risk perception. This effect is significant in Germany, the U.S., and Japan. A political right scaled ideology results in a lower likelihood to express higher nuclear risk perception, though the effect is not significantly different from the reference category in any of the observed samples. Comparing left and right political orientation in separate analyses (not shown here) the results indicate that in the case of France, there is a significant lower likelihood to have high nuclear risk perception for respondents who have a right political orientation compared to respondents who have a left political orientation. In the case of Great Britain, this effect cannot be observed, indicating that there is no significant different relationship between party affiliation and the likelihood to perceive nuclear power as very or extremely dangerous. I therefore summarize that the expected gap between left and right political orientation can be observed in all countries, although this effect varies across countries and is not statistically significant in Great Britain.

In this analysis, trust is measured on the one hand in trust in governance and on the other hand in the overall trust in people. For both measures, the reference category is the group of respondents who express that they do not trust, either in the government or in people. It is expected that respondents who do not trust the government or other people are more concerned about nuclear technology. Assumed is a negative or inverse relationship between trust and nuclear risk perception, i.e. higher levels in trust are related to lower levels of nuclear risk perception. In the case of trust in governmental institutions the expected negative relationship can be observed in almost all countries. This relationship is very clearly pronounced in France, where respondents who trust the government or have no preference have a significantly lower likelihood to perceive nuclear energy as highly dangerous. In the German sample there is a different pattern. Those who trust and do not trust the government are equally concerned about the dangers of nuclear technology. Respondents who do not express specific trust or distrust in the German government are significantly less likely to perceive nuclear as highly dangerous. One possible interpretation of Germany's result is that the nuclear issue is an issue that concerns people who are willing to express their trust or distrust to the given political situation. The German case for trust in people reveals a relationship that is counter-intuitive to the expected negative relationship. Those who trust or express no specific trust-tendency are equally more likely to be more concerned about nuclear technology than respondents who express to not trust other people. The expected negative relationship between trust in people and nuclear risk perception can be observed in all other countries, but the estimated effects only show significant differences in the U.S., Great Britain, and Japan. The relationship of trust and nuclear power, though indicating an inverse relationship, does not provide a homogeneous pattern in the international comparison for both trust variables. Further international comparative research needs to test, if the German case represents an outlier.

Economic values are expected to be an influential factor on nuclear risk perception. It is expected that nuclear technology is an essential element for a country's future economic prosperity. Proponents of economic growth should therefore be less likely to perceive nuclear technology as highly dangerous. The effect of a belief system in favor for economic growth seems not to be strong in the international comparison because the assumption can only be supported by two out of five samples. The expected negative relationship of respondents who favor economic growth instead of environmental protection is only significantly different in France and in Germany.

The Knowledge-Support-Hypothesis assumes that respondents who believe that they know more or better about environmental threats are less likely to express high levels of nuclear risk perception. People in all five observed country sample who believe that environmental threats are exaggerated are also less likely to perceive nuclear technology as very or extremely dangerous to the environment. This hypothesis cannot be rejected though the effect is negative but not significant on the 5 % significance level in Japan. When asked how much people know about the causes of environmental problems, only respondents in Japan who express to know more about the causes are significantly more likely to express high levels of risk perceptions. In the remaining four countries, there is no clear relationship observable.

The last value-question included in the model to detect an individualistic or collectivistic tendency to solve environmental problems does not show significantly different likelihoods from zero and does not indicate a homogeneous relationship across all countries. In the German, French, and Japanese sample more collectivistic oriented people have the tendency to be more likely to express higher risk perception. In Great Britain there is tendency for collectivistic oriented people to have a lower likelihood to express higher levels of nuclear risk perception. In the U.S. sample there is basically no observable tendency. It is possible that due to the operationalization of the variable the variable is week indicator for a collectivistic or an individualistic value preference. I therefore refrain from generalizing the results and only want to indicate that with the given data and chosen design, there is no observable significant difference between people with a rather collectivistic or individualistic world view.

Table 5: Marginal effects of full models in all five countries

	M4 U.S.		M4 Great Britain		M4 France		M4 Germany		M4 Japan	
Gender (0=male)										
female	0.151***	(5.08)	0.129**	(3.28)	0.0791**	(2.72)	0.137***	(4.02)	0.0879*	(2.44)
Age (0=<30)										
30–44	0.0301	(0.68)	-0.0517	(-0.71)	0.00305	(0.04)	0.0537	(1.06)	0.0740	(1.37)
45–59	-0.0235	(-0.53)	-0.181*	(-2.50)	-0.0296	(-0.38)	0.00099	(0.02)	0.0329	(0.6)
60–74	-0.146**	(-2.90)	-0.191*	(-2.36)	-0.115	(-1.37)	-0.0207	(-0.37)	0.00723	(0.13)
75–90	-0.208**	(-3.08)	-0.0699	(-0.60)	-0.248**	(-2.70)	-0.00374	(-0.05)	-0.0739	(-1.03)
Urbanity (0=city)										
town/small city	-0.0341	(-0.95)	-0.124**	(-2.81)	0.00634	(0.17)	0.027	(0.72)	0.0122	(0.32)
village	n.a.	n.a.	-0.0969	(-1.88)	-0.0212	(-0.60)	-0.0298	(-0.75)	-0.0155	(-0.36)
Education (0= no/lowest degree)										
intermediate secondary	0.0241	(0.24)	-0.00358	(-0.06)	-0.0680	(-1.44)	-0.0154	(-0.40)	n.a.	n.a.
secondary	-0.0572	(-0.68)	0.0843	(1.47)	-0.0817	(-1.68)	-0.0553	(-1.13)	0.0687	(1.41)
university	-0.194*	(-2.21)	0.163*	(2.53)	-0.118*	(-2.27)	-0.132*	(-2.34)	0.0985	(1.68)
Income (0=first tercile)										
second tercile	-0.0297	(-0.77)	-0.0441	(-0.79)	-0.0856*	(-2.51)	-0.00921	(-0.23)	0.0831	(1.94)
third tercile	-0.142***	(-3.50)	-0.112	(-1.83)	-0.118**	(-3.10)	-0.0193	(-0.46)	-0.0643	(-1.51)
Occupation (0=no occupation)										
part time	0.0749	(1.84)	-0.0140	(-0.27)	0.00904	(0.2)	-0.0545	(-1.14)	-0.0247	(-0.55)
full time	0.0546	(1.51)	0.0247	(0.40)	-0.123**	(-2.68)	0.000667	(0.02)	-0.0284	(-0.63)
Party affiliation (0=center/non)										
left	0.126***	(3.68)	0.0141	(0.29)	0.0439	(1.2)	0.0947*	(2.4)	0.304***	(3.36)
right	-0.0280	(-0.76)	-0.0602	(-1.28)	-0.0738	(-1.94)	-0.0842	(-1.80)	-0.0603	(-1.49)
Trust government (0=distrusting)										
no preference	-0.0156	(-0.43)	-0.0156	(-0.33)	-0.0769*	(-2.35)	-0.108**	(-2.80)	-0.0471	(-1.23)
trusting	-0.0441	(-1.24)	-0.0458	(-0.98)	-0.0968*	(-2.28)	-0.0157	(-0.36)	-0.00806	(-0.13)
Trust people (0=distrusting)										
no preference	-0.0440	(-1.20)	-0.142**	(-2.66)	-0.0420	(-1.36)	0.0954*	(2.38)	-0.0726*	(-2.02)
trusting	-0.0828*	(-2.28)	-0.168**	(-3.10)	-0.0118	(-0.33)	0.101**	(2.72)	-0.0403	(-0.90)
Environment (0=worry not too much)										
worry too much	0.0390	(1.17)	0.0884	(1.90)	0.00356	(0.11)	0.0287	(0.77)	-0.00445	(-0.10)
Economic growth (0=disagree)										
agree on more growth	0.00633	(0.21)	0.0409	(1.06)	-0.0832**	(-2.95)	-0.124***	(-3.84)	-0.0515	(-1.55)
Knowledge threat (0= not exaggerated)										
exaggerated	-0.107**	(-3.21)	-0.164***	(-3.64)	-0.129***	(-4.17)	-0.168***	(-4.34)	-0.0363	(-0.84)
Knowledge causes (0=not knowing)										
knowing much	-0.0115	(-0.36)	-0.0507	(-1.25)	0.0323	(1.14)	0.00365	(0.11)	0.0913*	(2.36)
Worldview (0=individualistic)										
collectivistic	0.00226	(-0.07)	-0.0566	(-1.45)	0.0520	(1.79)	0.0304	(0.87)	0.0549	(1.7)
Pseudo R^2	0.133		0.132		0.117		0.116		0.052	
N	1057		563		1192		811		908	

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Logistic regression coefficients displayed as marginal effects

6.6. Conclusion

I draw a conclusion based on the analyzed country samples of the U.S., Great Britain, France, Germany, and Japan (compare for a summary of the above discussed results Table 4). There are significant relationships quite similar in all five countries. Subgroups in all five societies that are more likely to express higher nuclear risk perceptions are women, younger people and people who have a political left party affiliation, as well as people who believe that environmental threats are not exaggerated.

From the data in the U.S., I conclude that there is a strong group with high socio-economic status that perceives nuclear as less dangerous compared to younger people, lower educated people, and individuals with lower income. The country is not divided but the data reveal that there is no powerful majority which perceives nuclear power as dangerous for the environment. Trust in government is not an important factor for nuclear risk perception as well as nuclear power seems not to be perceived as a necessary force for economic growth. The anti-nuclear revolution in the U.S. is more likely to be supported by people who are holding a left political ideology, by women of all age and of all educational background, since the negative education effect is stronger for men than for women.

A higher nuclear risk perception and, hence, probably anti-nuclear opinions in Great Britain are most likely to be perceived by younger citizens and people living in urban areas, as well as better educated people. It is an open question whether the anti-nuclear movement in the future can mobilize all parts of society.

The French nuclear project is successful and it seems that either the nuclear project could build its support structure or the French political system was the ideal sandbox to develop a French nuclear system. There is no support from the left wing political ideology to continuously stir the fears of nuclear power in the public debate. Women and young people are left alone and pressed in a social fabric that produced pro-nuclear ideology in its key institutions, university, financial power, and occupational prestige. Trust in government is an important mechanism in France for reducing individual's risk perception of nuclear power.

The German results in 2010 suggest that a subgroup of people, mostly better educated people, people with higher income, and people who believe in economic growth perceive nuclear as less dangerous. It is also a German phenomenon that people who trust other people are more concerned than people who distrust. Trust in Germany is a motivation not an obstacle for awareness of the nuclear threat. Trust can lead to higher social mobilization to go against the source of threat – the nuclear power plant. People who trust and who do not trust express the same levels of nuclear risk perception. Even if there is a gap in party ideology in Germany, it is not the case that the expressed trust in the government is dividing the alliance of people who perceive nuclear power as dangerous.

In Japan, prior to the Fukushima Daiichi accident, there were no incidents that indicated a strong evidence that the country is divided in expressing nuclear risk perception. Marginalized groups, such as women and people with a left wing ideology perceived nuclear power on average as more dangerous. It seems that the nuclear project in Japan is happening independently of public opinion and public consultation. The low explained variance in the Japanese model makes me doubting if the operationalization of the dependent and independent variable in Japan is appropriate for measuring nuclear risk perception and the relationship to socio-demographic variables properly.

Given more or less the same starting point of the nuclear project in all five countries, we see different patterns of nuclear risk perception and different developments of the nuclear project. Across all societies, there are people who perceive nuclear risk as dangerous as well as not dangerous. In the U.S., there is no vital development and a strong anti-nuclear movement, with a long tradition. In Great Britain, the nuclear project continues on a moderate level. After the Fukushima Daiichi accident, in Germany the nuclear project is faded out, a development that was on its way already before the accident in 2011. The data show that in Germany, nuclear risk perception is very high in almost all social groups. In Japan and France the nuclear project is about to survive even thought there were protests on the nuclear project, in the past in France and most recently in Japan. It is just the case, that in Japan as well as in France, a homogeneous group perceives nuclear as not dangerous, and are willing to support the technology, as I assume. It seems in Japan, that the population capitulated and there is no strong group that is able to say STOP! And in France only the socially weak people perceive nuclear as dangerous and could say STOP. An exclusive state, such as in France, Japan, and Great Britain, is able to govern nuclear technology independent of social protests or citizens' concerns.

I dare to argue, even though I cannot prove this assumption, that the historical development of the nuclear project in each country is reflected in the relationship of nuclear risk perception and socio-economic or value factors as analyzed in this chapter. Respondents in the U.S. that do not trust in government voice the weak role of the nuclear authorities in the U.S. to promote nuclear projects. In Great Britain, the anti-nuclear movement was supported by members of the elite and feminist groups. Both are reflected in the results. The reproduction of the French technocratic elite system can be found in the data structure, resulting, for example, in high trust in government authorities, the promotors of the nuclear project in France. Anti-nuclear attitudes are a common phenomenon across all social classes in Germany. People's political ideology is also represented in the federal and state government with the Green party. The ideology got institutionalized, in contrast to all other countries in this comparison. The data also indicate that people who are more concerned also trust more and maybe because of that are willing to mobilize other people. Nuclear technology, hence, is also a threat to social and political trust. The Japanese case reveals that a strong and nation wide anti-nuclear movement did not exit in 2010. The data show that beside women and people with a left-ideology there is no social group that can be addressed to be able to address strong fears of nuclear technology.

My conclusion is not free of critique. All data are cross sectional and measured at one particular time point. Any causal relationship is not provable. On the other hand, the historical as well as the empirical results, show that there are differences and that there are similarities. This chapter mentions political opportunity structures (Kitschelt, 1986) but a more systematic cross-national comparison is not performed. Instead I want to emphasize the arena concept, because I do not mention it within the theory section of my dissertation. Dieter Rucht (1990) and Ortwin Renn (2008) describe the conflictual interaction of different actors in their arena approach. According to this approach, within given structural settings, conflicting interactions take place between different actors. In the arena approach, the audience has not a passive role but is an important factor that can shape the discourse. Conflicting parties, do not only anticipate what effect their action will have on the conflicting party but also how the audience, as the third party will evaluate the specific action. The history of the nuclear project is a history of technological development and social protest at the same time. It is a social process and an empirical question whether societies and citizens will accept nuclear technology in the future or if the technology proves to be too dangerous for human living on earth.

6.7. Appendix

Regression table U.S.

Table 6: Nuclear risk perception in the U.S. (logistic regression with marginal effects as coefficients).

	M1		M2		M3		M4	
Gender (0=male)								
female	0.189***	(6.39)	0.185***	(6.34)	0.167***	(5.72)	0.151***	(5.08)
Age (0=<30)								
30–44	-0.0284	(-0.62)	0.0284	(0.63)	0.0276	(0.63)	0.0301	(0.68)
45–59	-0.0956*	(-2.09)	-0.0287	(-0.63)	-0.0245	(-0.55)	-0.0235	(-0.53)
60–74	-0.241***	(-5.04)	-0.173***	(-3.55)	-0.156**	(-3.13)	-0.146**	(-2.90)
75–90	-0.290***	(-4.55)	-0.244***	(-3.83)	-0.215**	(-3.22)	-0.208**	(-3.08)
Urbanity (0=city)								
town/small city	0.00921	(0.24)	-0.0410	(-1.13)	-0.0351	(-0.98)	-0.0341	(-0.95)
village	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	
Education (0= no/lowest degree)								
intermediate secondary			0.0122	(0.13)	0.0316	(0.32)	0.0241	(0.24)
secondary			-0.0789	(-0.99)	-0.0527	(-0.62)	-0.0572	(-0.68)
university			-0.220**	(-2.67)	-0.193*	(-2.19)	-0.194*	(-2.21)
Income (0=first tercile)								
second tercile			-0.0406	(-1.06)	-0.0325	(-0.84)	-0.0297	(-0.77)
third tercile			-0.174***	(-4.27)	-0.147***	(-3.64)	-0.142***	(-3.50)
Occupation (0=no occupation)								
part time			0.0588	(1.42)	0.0696	(1.69)	0.0749	(1.84)
full time			0.0407	(1.11)	0.0556	(1.53)	0.0546	(1.51)
Party affiliation (0=center/non)								
left					0.134***	(3.94)	0.126***	(3.68)
right					-0.0433	(-1.19)	-0.0280	(-0.76)
Trust governance (0=distrust)								
no preference					-0.0121	(-0.33)	-0.0156	(-0.43)
trusting					-0.0362	(-1.01)	-0.0441	(-1.24)
Trust people (0=distrust)								
no preference					-0.0368	(-1.01)	-0.0440	(-1.20)
trusting					-0.0844*	(-2.32)	-0.0828*	(-2.28)
Environment (0=worry not too much)								
worry too much							0.0390	(1.17)
Economic growth (0=disagree)								
agree on more growth							0.00633	(0.21)
Knowledge threat (0= not exaggerated)								
exaggerated							-0.107**	(-3.21)
Knowledge causes (0=not knowing)								
knowing much							-0.0115	(-0.36)
Worldview (0=individualistic)								
collectivistic							0.00226	(0.07)
Pseudo R^2	0.057		0.103		0.126		0.133	
N	1057		1057		1057		1057	

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Logistic regression coefficients displayed as marginal effects

Regression table Great Britain

Table 7: Nuclear risk perception in Great Britain (logistic regression with marginal effects as coefficients).

	M1		M2		M3		M4	
Gender (0=male)								
female	0.165***	(4.27)	0.161***	(4.08)	0.150***	(3.81)	0.129**	(3.28)
Age (0=<30)								
30–44	-0.0463	(-0.67)	-0.0293	(-0.40)	-0.0213	(-0.29)	-0.0517	(-0.71)
45–59	-0.205**	(-3.01)	-0.185*	(-2.56)	-0.164*	(-2.25)	-0.181*	(-2.50)
60–74	-0.234**	(-3.20)	-0.240**	(-3.16)	-0.200*	(-2.53)	-0.191*	(-2.36)
75–90	-0.109	(-1.02)	-0.139	(-1.26)	-0.0575	(-0.50)	-0.0699	(-0.60)
Urbanity (0=city)								
town/small city	-0.131**	(-2.87)	-0.129**	(-2.84)	-0.117**	(-2.61)	-0.124**	(-2.81)
village	-0.109*	(-2.06)	-0.111*	(-2.15)	-0.0916	(-1.79)	-0.0969	(-1.88)
Education (0= no/lowest degree)								
intermediate secondary			-0.0273	(-0.45)	0.00537	(0.09)	-0.00358	(-0.06)
secondary			0.0420	(0.73)	0.0891	(1.55)	0.0843	(1.47)
university			0.120	(1.86)	0.166**	(2.62)	0.163*	(2.53)
Income (0=first tercile)								
second tercile			-0.0796	(-1.42)	-0.0517	(-0.93)	-0.0441	(-0.79)
third tercile			-0.175**	(-2.97)	-0.133*	(-2.18)	-0.112	(-1.83)
Occupation (0=no occupation)								
part time			-0.0145	(-0.28)	-0.0130	(-0.25)	-0.0140	(-0.27)
full time			0.0215	(0.35)	0.0244	(0.39)	0.0247	(0.40)
Party affiliation (0=center/non)								
left					0.0244	(0.49)	0.0141	(0.29)
right					-0.0826	(-1.76)	-0.0602	(-1.28)
Trust governance (0=distrust)								
no preference					-0.00315	(-0.07)	-0.0156	(-0.33)
trusting					-0.0346	(-0.73)	-0.0458	(-0.98)
Trust people (0=distrust)								
no preference					-0.128*	(-2.40)	-0.142**	(-2.66)
trusting					-0.157**	(-3.03)	-0.168**	(-3.10)
Environment (0=worry not too much)								
worry too much							0.0884	(1.90)
Economic growth (0=disagree)								
agree on more growth							0.0409	(1.06)
Knowledge threat (0= not exaggerated)								
exaggerated							-0.164***	(-3.64)
Knowledge causes (0=not knowing)								
knowing much							-0.0507	(-1.25)
Worldview (0=individualistic)								
collectivistic							-0.0566	(-1.45)
Pseudo R^2	0.068		0.086		0.107		0.132	
N	563		563		563		563	

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Logistic regression coefficients displayed as marginal effects

Regression table France

Table 8: Nuclear risk perception in France (logistic regression with marginal effects as coefficients).

	M1		M2		M3		M4	
Gender (0=male)								
female	0.135***	(4.61)	0.0924**	(3.08)	0.0826**	(2.81)	0.0791**	(2.72)
Age (0=<30)								
30–44	-0.0468	(-0.53)	0.00163	(0.02)	0.000302	(0.00)	0.00305	(0.04)
45–59	-0.0470	(-0.55)	-0.0212	(-0.25)	-0.0338	(-0.42)	-0.0296	(-0.38)
60–74	-0.117	(-1.34)	-0.153	(-1.71)	-0.134	(-1.54)	-0.115	(-1.37)
75–90	-0.252**	(-2.65)	-0.302**	(-3.23)	-0.270**	(-2.87)	-0.248**	(-2.70)
Urbanity (0=city)								
town/small city	0.0467	(1.24)	0.00627	(0.16)	0.0111	(0.29)	0.00634	(0.17)
village	0.0414	(1.19)	-0.0103	(-0.28)	-0.0137	(-0.38)	-0.0212	(-0.60)
Education (0= no/lowest degree)								
intermediate secondary			-0.0637	(-1.31)	-0.0699	(-1.47)	-0.0680	(-1.44)
secondary			-0.0509	(-1.02)	-0.0668	(-1.37)	-0.0817	(-1.68)
university			-0.0824	(-1.56)	-0.0988	(-1.90)	-0.118*	(-2.27)
Income (0=first tercile)								
second tercile			-0.0921**	(-2.60)	-0.0854*	(-2.49)	-0.0856*	(-2.51)
third tercile			-0.133***	(-3.36)	-0.116**	(-2.99)	-0.118**	(-3.10)
Occupation (0=no occupation)								
part time			0.0128	(0.27)	0.0138	(0.29)	0.00904	(0.20)
full time			-0.142**	(-3.01)	-0.118*	(-2.49)	-0.123**	(-2.68)
Party affiliation (0=center/non)								
left					0.0632	(1.72)	0.0439	(1.20)
right					-0.0853*	(-2.25)	-0.0738	(-1.94)
Trust governance (0=distrust)								
no preference					-0.0794*	(-2.40)	-0.0769*	(-2.35)
trusting					-0.110*	(-2.57)	-0.0968*	(-2.28)
Trust people (0=distrust)								
no preference					-0.0397	(-1.29)	-0.0420	(-1.36)
trusting					0.00968	(0.26)	-0.0118	(-0.33)
Environment (0=worry not too much)								
worry too much							0.00356	(0.11)
Economic growth (0=disagree)								
agree on more growth							-0.0832**	(-2.95)
Knowledge threat (0= not exaggerated)								
exaggerated							-0.129***	(-4.17)
Knowledge causes (0=not knowing)								
knowing much							0.0323	(1.14)
Worldview (0=individualistic)								
collectivistic							0.0520	(1.79)
Pseudo R^2	0.032		0.065		0.097		0.117	
N	1192		1192		1192		1192	

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Logistic regression coefficients displayed as marginal effects

Regression table Germany

Table 9: Nuclear risk perception in Germany (logistic regression with marginal effects as coefficients).

	M1		M2		M3		M4	
Gender (0=male)								
female	0.157***	(-4.83)	0.159***	(-4.65)	0.160***	(-4.81)	0.137***	(4.02)
Age (0=<30)								
30–44	0.038	(-0.75)	0.0513	(-0.98)	0.0494	(-0.98)	0.0537	(1.06)
45–59	-0.000525	(-0.01)	0.0119	(-0.24)	-0.00822	(-0.17)	0.00099	(0.02)
60–74	-0.0286	(-0.54)	-0.0418	(-0.71)	-0.0453	(-0.79)	-0.0207	(-0.37)
75–90	-0.0291	(-0.40)	-0.0502	(-0.63)	-0.0487	(-0.65)	-0.00374	(-0.05)
Urbanity (0=city)								
town/small city	0.0176	(-0.45)	0.00863	(-0.22)	0.0196	(-0.51)	0.027	(0.72)
village	-0.0325	(-0.82)	-0.0459	(-1.13)	-0.0285	(-0.71)	-0.0298	(-0.75)
Education (0= no/lowest degree)								
intermediate secondary			-0.00608	(-0.15)	-0.0169	(-0.43)	-0.0154	(-0.40)
secondary			-0.0285	(-0.55)	-0.0486	(-0.97)	-0.0553	(-1.13)
university			-0.0869	(-1.57)	-0.142**	(-2.59)	-0.132*	(-2.34)
Income (0=first tercile)								
second tercile			-0.00346	(-0.08)	-0.00837	(-0.20)	-0.00921	(-0.23)
third tercile			-0.0172	(-0.40)	-0.0209	(-0.49)	-0.0193	(-0.46)
Occupation (0=no occupation)								
part time			-0.0622	(-1.22)	-0.0603	(-1.22)	-0.0545	(-1.14)
full time			0.00196	(-0.04)	-0.0065	(-0.15)	0.000667	(0.02)
Party affiliation (0=center/non)								
left					0.130**	(-3.18)	0.0947*	(2.40)
right					-0.0642	(-1.33)	-0.0842	(-1.80)
Trust governance (0=distrust)								
no preference					-0.108**	(-2.72)	-0.108**	(-2.80)
trusting					-0.0516	(-1.12)	-0.0157	(-0.36)
Trust people (0=distrust)								
no preference					0.101*	(-2.51)	0.0954*	(2.38)
trusting					0.106**	(-2.78)	0.101**	(2.72)
Environment (0=worry not too much)								
worry too much							0.0287	(0.77)
Economic growth (0=disagree)								
agree on more growth							-0.124***	(-3.84)
Knowledge threat (0=not exaggerated)								
exaggerated							-0.168***	(-4.34)
Knowledge causes (0=not knowing)								
knowing much							0.00365	(0.11)
Worldview (0=individualistic)								
collectivistic							0.0304	(0.87)
Pseudo R^2	0.027		0.032		0.077		0.116	
N	811		811		811		811	

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Logistic regression coefficients displayed as marginal effects

Regression table Japan

Table 10: Nuclear risk perception in Japan (logistic regression with marginal effects as coefficients).

	M1		M2		M3		M4	
Gender (0=male)								
female	0.0845**	(2.63)	0.0810*	(2.29)	0.0835*	(2.36)	0.0879*	(2.44)
Age (0=<30)								
30–44	0.0924	(1.76)	0.0766	(1.41)	0.0736	(1.38)	0.0740	(1.37)
45–59	0.0196	(0.38)	0.0246	(0.45)	0.0225	(0.42)	0.0329	(0.60)
60–74	0.0182	(0.35)	-0.00574	(-0.11)	0.00779	(0.14)	0.00723	(0.13)
75–90	-0.0737	(-1.09)	-0.0893	(-1.29)	-0.0730	(-1.01)	-0.0739	(-1.03)
Urbanity (0=city)								
town/small city	-0.0121	(-0.32)	-0.00805	(-0.21)	0.00536	(0.14)	0.0122	(0.32)
village	-0.0379	(-0.89)	-0.0379	(-0.87)	-0.0238	(-0.55)	-0.0155	(-0.36)
Education (0= no/lowest degree)								
intermediate secondary			n.a.	n.a.	n.a.	n.a.	n.a.	
secondary			0.0666	(1.38)	0.0668	(1.38)	0.0687	(1.41)
university			0.103	(1.77)	0.102	(1.74)	0.0985	(1.68)
Income (0=first tercile)								
second tercile			0.0895*	(2.07)	0.0858*	(2.00)	0.0831	(1.94)
third tercile			-0.0525	(-1.22)	-0.0494	(-1.15)	-0.0643	(-1.51)
Occupation (0=no occupation)								
part time			-0.0402	(-0.88)	-0.0254	(-0.56)	-0.0247	(-0.55)
full time			-0.0375	(-0.84)	-0.0234	(-0.52)	-0.0284	(-0.63)
Party affiliation (0=center/non)								
left					0.304**	(3.22)	0.304***	(3.36)
right					-0.0583	(-1.47)	-0.0603	(-1.49)
Trust governance (0=distrust)								
no preference					-0.0492	(-1.28)	-0.0471	(-1.23)
trusting					-0.0191	(-0.29)	-0.00806	(-0.13)
Trust people (0=distrust)								
no preference					-0.0771*	(-2.17)	-0.0726*	(-2.02)
trusting					-0.0430	(-0.96)	-0.0403	(-0.90)
Environment (0=worry not too much)								
worry too much							-0.00445	(-0.10)
Economic growth (0=disagree)								
agree on more growth							-0.0515	(-1.55)
Knowledge threat (0= not exaggerated)								
exaggerated							-0.0363	(-0.84)
Knowledge causes (0=not knowing)								
knowing much							0.0913*	(2.36)
Worldview (0=individualistic)								
collectivistic							0.0549	(1.70)
Pseudo R^2	0.013		0.028		0.043		0.052	
N	908		908		908		908	

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Logistic regression coefficients displayed as marginal effects

7. Empirical research II: The Fukushima effect on nuclear risk perception

7.1. Introduction

On March 11, 2011 a major natural disaster hit the eastern Japanese coast and led to a humanitarian catastrophe and to a mayor nuclear disaster which is now called the Fukushima Daiichi nuclear accident. Both events were a shock for the Japanese society as well as for humans around the world who could follow the dramatic event on the news. The nuclear accident can be perceived as a moment of global discontinuity putting forth the question of how dangerous people in different countries perceive nuclear power stations.

In this chapter, I will discuss how risk is defined from a technical perspective, an expert's view, and how in contrast laypeople intuitively perceive risks. I am interested how laypeople change their risk perception in case of the immediate evidence of a nuclear accident at some place in the world. One question I am asking is whether a major nuclear accident widens the gap in public's risk perception of nuclear energy, leading to more extreme views, i.e. to polarization; or does an accident lead to a harmonization of risk perception in the population, i.e. to solidarity? I artificially try to paint a picture of on one hand a naive layperson completely relying on intuition, emotions, and heuristics when evaluating nuclear risk. On the other hand, I refer to the prototype of an analytical expert who calculates risk perception by the expected utility of negative outcome and the probability of a dangerous event. I want to remark that I stereotype and assume that in reality risk evaluation is an interplay of intuitive emotions and analytical reasoning, or as Finucane and colleagues (2003) title their book chapter 'Judgment and decision making: the dance of affect and reason'.

I test my assumptions with empirical data of people's views on risk perception before and after the nuclear accident of Fukushima using data from the International Social Survey Programme (ISSP) Environment Module III (ISSP, 2012). I furthermore see the unexpected event of the Fukushima Daiichi nuclear accident as a natural experiment, that divides the population in people who evaluated their nuclear risk perception before the nuclear accident and people who assessed nuclear risk after the accident using the new information of a major nuclear accident. I also take into consideration the assumption that different subgroups within a society are more likely to have higher or lower levels of risk perception. I therefore want to know to what degree changes in nuclear risk perception differ between different subgroups.

This research question is in part based on a co-authored project with Dr. Rudolf Farys (University of Bern, Switzerland) and Dr. Thomas Häussler (University of Bern, Switzerland). The data and methods part as well as the result part of this chapter are a result of the co-authored project. In this parts, I use the term 'we' to emphasize that we all three contributed to the content. I want to emphasize that I owe Dr. Rudolf Farys the implementation of the research idea in the statistical model as well as the statistical results and graphical representation. The theory part as well as the conclusion are my own work. I therefore use the term ‘I’ to indicate a clear separation of my own contribution and the shared contribution to the research question.

7.2. Theoretical overview

There is no unanimously defined concept or risk in the scientific community (cf., Rosa, 1998; Aven and Zio, 2014; Aven, 2012b; Aven et al., 2011; Aven and Renn, 2009; Campbell and Currie, 2006). In the following section I differentiate between a technical concept of risk and an intuitive concept of risk. The former is based on the rational calculation of expected values, the later is based on an intuitive evaluation of uncertain outcomes. For a discussion of the definition of risk see also Section 2, especially Section 2.4.

In the technical risk concept, risk is expressed as a function of two components: the first component is the harm of a negative event multiplied with the second component, probability (Campbell and Currie, 2006, 150). Risks perceived from this point of view is understood as an “expected loss” or a “expected disutility” or the “probability of an adverse outcome” and has a negative connotation (Aven and Renn, 2009, 1). The decision making process behind the technical risk evaluation is to minimize the expected risk or the expected disutility.

According to classical decision making theory, the basic rationale behind the decision making process is to maximize expected utility or vice vera, to minimize expected losses (Renn, 2008, 103). Proponents of this view assume that individuals are able to reflect the expected costs and benefits of each decision option. It is furthermore assumed that individuals simultaneously assign subjective probabilities to the occurrence of each option. Renn describes risk from that perspective as: “Risk in this sense represents the net effect of negative or positive consequences associated with each option (magnitudes) and the assignment of probabilities to each outcome” (Renn, 2008, 103). The assumption of rational decision making holds for situations in which an option has different consequences, weighted with different probabilities. In the case of nuclear risk a rational actor is assessing different consequences such as economic benefits, risk for health, and environmental consequences. Nuclear risk could even be perceived as a multi-optional risk, given the set of nuclear risks, such as the risk of nuclear weapons, nuclear energy, and nuclear waste disposal.

The multi-dimensionality of the evaluation process and the rationally assigned weights and probabilities is a reason that the concept of a rational actor fits in theory, but leaves room for criticism. This concept is not easily to apply in everyday decision making processes in real life situations under limited time and information resources. Laypeople are not well trained to process probabilistic information (Dietz and Stern, 1995; Tversky, 1972; Jaeger et al., 2001). Laypeople tend to evaluate uncertainty not as probabilities but turn to different non-probabilistic cognitive processes when assessing the unknown (Aven, 2012b, 2011). Furthermore, the information processing process of perceiving, evaluating, and forming beliefs varies between individuals and depends on the specific context and the given information sources (Renn, 1992; Kasperson et al., 1988).

From a social science point of view, it is useful to use a broader concept of risk when assessing individuals risk perception. According to Aven and Renn (2009, 3–4) a broader concept of risk is a concept that (a) does not distinguish between desirable and undesirable outcomes; (b) speaks of uncertainties and does not assume probabilities and expected values; (c) evaluates if outcomes are at stake and is not based on the evaluation of specific consequences. To summarize, the broader risk concept encompasses everything that humans value. This measure is not based on precise measures of uncertainty, such as probabilistic point estimators. Risk furthermore is not defined through specific and precisely defined consequences of an event or action, but rather by a dialogical process of evaluated outcomes; by evaluating something of human value, that is potentially at stake.

Rosa (1998, 28) provides a broader definition of risk that is based on the two dimensions of uncertainty and outcomes at stake: "Risk is a situation or event where something of human value (including humans themselves) has been put at stake and where the outcome is uncertain." This definition still implies that risk and risk perception are separate items. Rosa's definition assumes that there is a world (out there) that has risks and that this world is independent of individual's perception, as Aven and Renn claim (2009, 5). According to Aven and Renn, the concept of individual's risk evaluation beyond the rational framework is not only an assessment of the seriousness of a risk, but also implies a normative judgement of its perceived acceptability and tolerability. The authors (Aven and Renn, 2009, 6) define risk as a subjective evaluation of events and outcomes in an uncertain world: "Risk refers to uncertainty about and severity of the event and consequences (or outcomes) of an activity with respect to something that human value." Risk from this point of view is an evaluation process of the uncertainty of an event and the uncertainty about the potential consequences (compare Section 2.4.3). This definition in a second step allows a normative judgement with respect to something that people value. Risk perception then can be understood as a multidimensional judgment process: "Risk perception, in general, denotes the processing of physical signals and/or information about potentially harmful events or activities, and the formation of a judgement about seriousness, likelihood and acceptability of a respective event or activity" (Renn, 2008, 98). To summarize, risk perception is a person's judgement about a risk. Risk in Aven and Renn's concept is mentally constructed by assessing the uncertainty and does not exist independent of the observer (Aven and Renn, 2009, 8). Risks are not external features but objects of subjective knowledge, or as Beck claims: "risks are risks in knowledge" (Beck, 1992, 55). Any individual uncertainty judgement is based on the available information and personal experience, values and beliefs, reflecting a broad spectrum of uncertainty aspects, that are ignored in a concept of risk, evaluating risks as an expected value of probability and consequences.

Risks expressed as expected values is criticized because by this process of risk assessment potential harm is not adequately reflected (Beck, 1992; Aven and Renn, 2009; Renn, 2008). Laypeople's judgement of risks, on the contrary, is based on simplified judgments procedures (heuristics) and weighting patterns that are able to overweight or to ignore potential harm. Often the optimal strategy is to avoid major losses than to maximize expected benefits (Kahneman and Tversky, 1979; Luce and Weber, 1986; Covello, 1983; Renn et al., 1992). Renn (2008, 98) also mentions that laypeople's risk judgement weights the consequences of an event or action higher than its probability. Renn further points out (referring to Sparks and Shepherd, 1994; Frewer et al., 2002) that laypeople perceive uncertainty as a fundamental gap in knowledge and do not refer to the concept of probability distributions to overcome knowledge gaps and blind spots of uncertainty. In the non-expert's world, uncertainty about the potential occurrence of a risk is a strong criteria depicting how people perceive and accept risks (Renn, 2008, 102–103).

The concept of expected value and its assumption of deriving probabilities to potential outcomes is a complex process of information processing. Human beings usually use simpler ways, as rules of thumbs, to assess risks and to judge harmful situation. For example, in the case of the Fukushima Daiichi accident I assume that people all over the world rather intuitively than rationally assessed the risk of this nuclear accident as a harmful outcome or a dangerous situation. In this case, judgement of a new situation is assumed to be intuitively connected or linked to previous information of similar events, a-priori beliefs and attitudes, furthermore to intuitively experienced emotions and easily accessible associations of that event. Given that in laypeople's risk evaluation all of these factors play an important part in judging risks, laypeople's risk evaluation should differ from experts' risk evaluation and have the characteristics of an intuitive judgement.

As presented in Section 4.2.1, from a scientific point of view, several factors of an intuitive judgment under uncertainty, so called biasing factors or heuristics, have been detected and discussed (compare for example Tversky and Kahneman, 1973, 1974; Lichtenstein et al., 1978; Rohrmann and Renn, 2000; Rottenstreich and Tversky, 1997; Rohrmann, 1994; Gigerenzer, 1991). In the case of the 'availability bias', as well as the 'anchoring effect bias', it is assumed that people judge the risk of an event as more likely when similar events are known and immediately mentally available. Similarly, the 'representativeness bias' also indicates that events that are directly and emotionally experienced are perceived as known and their likelihood gets more weight than unfamiliar events, represented by mere numbers and without a narrative. In the case of a nuclear accident, it can be assumed that the event triggers all three biases and makes people overestimate the likelihood of a new nuclear accident, as well as develop a pessimistic view of the potential consequences of the actual nuclear disaster at the Fukushima Daiichi power plant. The 'avoidance of cognitive dissonance bias' assumes that people, after processing new information, try to ignore information that challenges their existing belief system (Rohrmann and Renn, 2000; Rohrmann, 1994). From that point of view, a-priori supporters and opponents of nuclear technology should drift further apart in case of a new accident. Supporters should try to keep their doubts about nuclear risks as low as possible, by using the information to downplay the risk, whereas opponents should use the information to emphasize and exaggerate their a-priori judgement of nuclear risk. People who hold both views, though, should be influenced by the availability bias and change their views towards a more pessimistic perception of nuclear power. The discussion on heuristic biases reveals that people's risk judgement is an interplay of cognitive processes, existing belief structures and available information. As a result, their evaluation is always influenced by qualitative aspects of human reasoning and risk judgement. It is either biased towards one extreme of mere arithmetic rationality, a calculated process, or the other extreme of mere intuition, a process that is based on feeling and perception. The question, therefore, is not whether the view is biased, but to what degree. Followed by the normative question, whether these biased views harm the social order and the well being of the society and nature, now and in the future.

7.2.1. The concept of heuristics and a critique

I want to focus my thoughts again on the concept of heuristics and biases, developed by Tversky and Kahneman Tversky and Kahneman, 1974. First, I want to understand why something human judge is called biased. I then want to point out that the concept of heuristics can be used as one potential explanation for how human reasoning can lead to more extreme results when judging the risk of nuclear power. I also want to open up the space for a criticism of the concept of heuristics and biases by discussing the underlying normative concept; a normative concept, that allows to call a judgment under uncertainty biased or error (Gigerenzer, 1991).

In the first step of my more detailed explanation of heuristics and biases I hypothesize that heuristics can lead to more extreme opinions about nuclear power's danger, on the optimistic as well as on the pessimistic sides of nuclear power's risk evaluation scale. To do so, I imagine a fictive population divided into the prototype of laypeople and the prototype of experts. The underlying assumption I make is that from a layperson's perspective, nuclear risk is more likely to be perceived as 'extremely dangerous,' whereas from an expert's point of view, nuclear risk is more likely to be perceived as 'not at all dangerous'. The basic question is how people assess the risk of nuclear power. How do respondents quantify a risk? In the heuristic and bias concept the quantified measure of risk should be a quantity of the likelihood and the dangerous consequences of nuclear power. The assumption is that people use heuristics to make a simplified judgment of the true probability and harm of an event, a judgment under uncertainty due to limited information and time pressure. Heuristics help to simplify that complex process of information processing. While applying heuristics, according to Tversky and Kahneman, systematic errors can occur leading to observable biases (Tversky and Kahneman, 1974, 1124). The basic question for me is whether individuals, both the prototype of experts and laypeople, are overestimating or underestimating the risk of nuclear power (compare

Tversky and Kahneman, 1974, 1124). How does the object of risk occur from an judging perspective? Are the contours of the risk clear or unclear, and therefore under- or overestimated?

The *representativeness heuristic* is used when people judge the likelihood that a certain process A will lead to a certain outcome B. In the case of nuclear power, the judgment is the likelihood that nuclear power plants will produce a negative outcome, such as a nuclear accident. In such a case, information about the existing nuclear power plants (A) will lead to the judgment of how likely a nuclear accident (B) will occur. To assess probabilities of dangerous events different processes can be used, depending on the available information and an observer's view. Nuclear power can be perceived as safe technology if the observer counts the number of accidents in relation to the known accidents of nuclear power plants locally, using a narrow time-space dimension. If an observer refers intuitively to major accidents, as base line category for the probability judgment, using a global perspective as time-space dimension, nuclear power can be perceived as extremely dangerous. How people interpret the "characteristics of a process" (Tversky and Kahneman, 1974, 1125) influences individual's judgment.

The gambler's fallacy is an example of how different views can lead to a polarization of nuclear risk perception in a population. The gambler's fallacy occurs when chance is perceived as a process that automatically leads to an equally balanced occurrence of events (Tversky and Kahneman, 1974, 1125). In the case of a very low expected probability of a nuclear accident, the fallacy could be the following: since there has not been an accident in the past, there will be no accident in the future. This group of people ignores that chance means that nuclear accidents can happen at any time, independent of past events and of the expected likelihood of an nuclear accident. On the other hand, the gambler's fallacy also leads to an overestimation of nuclear risk for when after a long sequence of no accidents someone expects the next accident to happen. The nature of chance has no self-correcting mechanisms which means that a long period with no accident events does not mean that the next event is more likely to be an accident.

Two aspects, related to what Tversky and Kahneman call the 'representativeness heuristic' are worth mentioning from my point of view. Both point to the description and the consistency of arguments that form someone's judgments under uncertainty, and point to the concrete evidence. Tversky and Kahneman call the process in which the consistency of a description guides someone's judgment and not the actual evidence "insensitivity to predictability" (Tversky and Kahneman, 1974, 1126). They furthermore term "illusion of validity" (Tversky and Kahneman, 1974, 1126) a process in which the occurrence of an event is primarily assessed based on how the available information represents the expected outcome. In both cases, if the information available about nuclear power matches the stereotypes of a safe technology, and is consistent in its description, any judgment of perceiving nuclear power as not dangerous is perceived as valid. On the other hand, a consistent and valid description of nuclear as a not safe technology will lead to a judgment of nuclear as an extremely dangerous technology. From my point of view, there is no solution for this problem and no correct answer, since even the evidence of nuclear accidents does not provide clear information and is an object which is subject to interpretation itself. Any nuclear accident can be perceived as an indicator of how safe or dangerous the technology is, it depends entirely on the consistent and valid interpretation. The measure of change in people's intuitive risk judgment, after a sudden event, can shield more light on the intuitive processes of risk perception, along with how emotions guide people's risk assessment.

The concept of *anchoring heuristic* can further be used as an explanation of how different starting points (anchors) can lead to different judgments of nuclear power's danger, especially when uncertainty is an important element of the assessment. If the starting point of the risk calculation is the worst imaginable case of a fatal nuclear accident, the perceived risk, i.e. the likelihood of an event and the outcomes of the event, of nuclear power should be high. Vice versa, if an individual focuses on the positive aspects of nuclear power as a starting point the intuitive judgment of a risk should be comparably low[74]. Tversky and Kahneman point out that according to their research, people have the tendency to overestimate the probability of "conjunctive events" and prefer these events over "disjunctive events", which in contrast are systematically underestimated (Tversky and Kahneman, 1974, 1129). In their example people prefer to draw a red marble at least seven times from a bag containing 90 % red marbles and 10 % white marbles, the conjunctive example, rather than drawing a red marble one time in seven trials from a bag containing 10 % red marbles and 90 % white marbles.

When evaluating the risk of nuclear power, the starting point, the anchor, is essential. What is perceived as a red marble in the above mentioned example? In the conjunctive example, from a prototype experts' point of view, red marbles are the events with no nuclear accident; a layperson's bag contains nuclear accidents as red marbles. All judgments will be biased based the given reference point. If the assertion is correct that people tend to prefer conjunctive over disjunctive events, experts as well as laypeople should have a tendency to ignore judgment mechanisms that are based on a disjunctive logic. Once again the true value of nuclear risk is unknown. Only empirical evidence over time will provide enough information for nuclear risk to be more precisely assessed. I think that the anchor is a strong predictor for the final assessment. It seems difficult to be able to see the anchor as a randomly chosen starting point and almost impossible to assess a risk sufficiently independent of the anchor point. That said, I believe that an anchor is in fact not a random choice but already conveys pertinent information for a final evaluation of risk.

An anchoring heuristic could be an explanation for why humans are willing to produce man made risks such as nuclear technology, by systematically evaluating low levels of risk perception, without having actual empirical evidence. Tversky and Kahneman provide some thoughts around the reason why conjunctive and disjunctive events can

[74] I here understand risk as the risk of a nuclear accident. Since the true probability of a nuclear accident is not known, I hesitate to describe the risk of nuclear power as 'overestimated' or 'underestimated'. I therefore say risk perception is perceived as high or low.

lead to underestimated risk in large scale processes planned, designed, and accomplished by human beings (Tversky and Kahneman, 1974, 1129). According to the authors' reasoning, events have an conjunctive character if a number of successful steps need to be carried out in order to reach a goal. In the case where there are many steps involved, this leads to an optimism and an overestimation of success and an underestimation of failure. At the same time, to avoid disjunctive events or to draw the red marble, it is underestimated that one element in this complex system will fail. Therefore, the risk of evaluating the complexity of a system is also underestimated. Since complex processes carry both elements, i.e. many steps in complex systems, it is highly likely to overestimate success and underestimate the likelihood of failure. A particular example, Tversky and Kahneman mention, for a disjunctive process is the risk assessment of a nuclear power plant. They state: "A complex system, such as a nuclear reactor or a human body, will malfunction if any of its essential components fails. Even when the likelihood of failure in each component is slight, the probability of an overall failure can be high if many components are involved. Because of anchoring, people will tend to underestimate the probabilities of failure in complex systems" (Tversky and Kahneman, 1974, 1129).[75]

Gerd Gigerenzer (1991) criticizes Tversky and Kahneman's concept of heuristics and biases. Gigerenzer points out that the concept of heuristics and biases an attempt to distinguish between a correct and an erratic way of human reasoning under uncertainty. He emphasizes that research should try to find ways and a language to explain rather than to judge human reasoning (Gigerenzer, 1991, 102). From his point of view, the assertion of biased probability estimations is based on a narrow concept of Bayesian reasoning and can be rejected when the frequentist theoretical framework is applied. The heuristic framework most often refers to situations in which single events are evaluated within a non-random data generating process. In these cases it is not possible to speak of probabilities and or to describe human judgment under uncertainty as biased from an expected true probability. The basic assumptions to derive probabilities are not met. According to Gigerenzer, the world of statistics speaks in different languages, a fact that has been widely ignored so far: "The existence of different statistical models of inference is a rich resource for developing theories about intuitive inference. This resource has been rarely touched, possibly because of the misleading normative view that statistics speaks with one voice" (Gigerenzer, 1991, 103). Only what deviates from a narrow statistical norm can be expressed as a biased evaluation of a situation or event. From a broader statistical point of view, this biased judgment disappears.

Gigerenzer suggests considering the structure of the environment as an important factor influencing human reasoning under uncertainty. Simple mathematical models, algorithms, or normative assumptions will too soon lead to deviations from an expected optimum. Not because of incorrect human reasoning, but because of aspects ignored in the existing environment (Gigerenzer, 1991, 107). Choosing to not apply the same algorithm over and over, again and again, to an existing problem could be the intuitively best

[75] Charles Perrow (Perrow, 1999) calls that sort of failures "normal accidents" because the design of the process is not able to be perfect and due to its complexity an accident is always likely to happen.

answer within a world of a changing environment. I conclude, that in this case, biased behavior is an indicator for deviation of an observer's perspective of the environment and respondents' point of views. Gigerenzer calls that phenomenon an environment's "*surplus* structure" (Gigerenzer, 1991, 107). This structure cannot be modeled in simple a-priori distributions or likelihood assumptions, as performed in the Bayesian model. A particularly different perception of time and space among individuals might lead to different perceptions of the reality. Gigerenzer suggests combining statistical theory and research on social cognition to better understand how humans adapt their decision making processes within a constantly changing environment. Using a narrow normative understanding of probabilistic reasoning, as done by the heuristic and bias concept, will itself mislead people to believe that human reasoning can be separated into right and wrong, an artificial separation as Gigerenzer demonstrates.[76]

Based on Gigerenzer's words, I think that an additional single event, such as a nuclear accident, could lead to fundamental changes within an individual's surplus structure and perception of the environment. I also believe that this judgment will depend on the a-priori anchor a person has intuitively set. Asking individuals to judge the risk of nuclear power before an accident might result in a judgment of confidence and/or skepticism in nuclear technology. The question remains for me, to what degree does the information of a nuclear accident really change an individual's risk judgment of nuclear power? Tversky and Kahneman believe that rational judgment is not only based on "internal consistency", i.e the compatibility with the probabilistic norms, but is also based on the entire inner and outer belief structure an individual is holding (Tversky and Kahneman, 1974, 1130). The avoidance of cognitive biases or cognitive dissonances, is an additional important heuristic in the process of how humans judge danger within their environment. I conclude that the heuristic and bias approach, as well as Gigerenzer's critical comments, indicate that human reasoning in uncertain circumstances is a complex process of information processing. Rational aspects are only part of the entire process. I assume that emotional aspects, as I will discussed next, are driving factors for human's judgment of risks, especially in the case of nuclear power, a subject with strong opponents, strong proponents, and people who hold both skeptical and supporting views.

7.2.2. Risk as feelings in case of a nuclear accident

In their risk as feelings hypothesis, Loewenstein and colleagues Loewenstein et al., 2001 point out that subjective feelings and emotional processes, such as the ability to imagine consequences or the personal exposure to an outcome, as well as the past history of

[76] Gigerenzer explains in many examples that probability theory is not violated, even if it is claimed by proponents of the heuristic and bias concept: "I have used classical demonstrations of overconfidence bias, conjunction fallacy, and base-rate neglect to show that what have been called "errors" in probabilistic reasoning are in fact *not* violations of probability theory. They only look so from a narrow understanding of good probabilistic reasoning that ignores conceptual distinctions fundamental to probability and statistics" (Gigerenzer, 1991, 109).

conditioning shapes individual's risk judgment (compare Section 4.2.5). In their concept objective features, such as the likelihood of an event or expected consequences are considered, but expected to be only partially influential in the risk assessment process. In social research (compare for example Zajonc, 1980; Wilson and Schooler, 1991; Damasio, 1994) affective reactions, based on vividness, immediacy, and experienced memories are considered indicators for expressing feelings of danger. According to Loewenstein et al. Loewenstein et al., 2001, the combination of emotional aspects and cognitive evaluation is a more valid indicator of how people perceive risks in their everyday context than what is perceived as rational reasoning in literature (compare for a discussion on the rational actor framework Jaeger et al., 2001; Rosa et al., 2014, Chapter 3).

As explained in Section 4.2.7, the *affect heuristic* (Slovic et al., 2004, 2007) is a process in which a stimulus consciously or unconsciously evokes a positive or negative feeling. Intuitively, a state is either judged as good or bad. This emotional reaction is understood as the experiential mode of thinking, in contrast to the analytical mode of thinking (Epstein et al., 1992; Epstein, 1994). It is called a heuristic because the information is intuitively remembered and this mental short cut allows for instant judgement of a situation. Slovic and colleagues argue that affect is an important aspect for rational decision making processes. Finucane et al. (2003) describe the interaction of the experiential and the analytic mode of thinking as the "dance of affect and reason."

The affect heuristic is based on the assumption that images of present or future events are marked or associated to various degrees, with negative and positive feelings. Depending on the emotional images stored a situation creates a somatic reaction when activated. This reaction is perceived consciously or unconsciously (Damasio, 1994). The intensity of the reaction differs, depending to the degree of which emotions are connected with the stimulating event (Slovic et al., 2007, 1335). Empirical research on the affect heuristic indicates that favorable feeling towards an activity or risk are increasing the benefits of that risk (Alhakami and Slovic, 1994; Finucane et al., 2000a). This means that the perceived risk is reduced by positively mapped emotional images associated with the risk, resulting in a more positive perception of that risk. The same mechanisms hold for negatively mapped images that lead to an increased perception of risks, reducing the perceived benefits of that risk. The interplay of affective images and analytic reasoning is influencing individuals risk assessment. Emotions are especially important in situations when empirical evidence is missing and "coldly rational" decision making processes become too dominant (Slovic et al., 2004, 319).

In the case of a nuclear accident, I assume that the different emotional aspects of intuitive images are important factors influencing individual's risk perception. In line with Whitfield and colleagues, I assume that individuals are "informal Bayesians" who hold strong a-priori beliefs and value laden images about a risk and are able to change that beliefs when medias are presenting new information about the risk (Whitfield et al., 2009, 427; footnote 8). In the case of nuclear power, it is assumed that people holding a positive attitude towards that technology will be immunized against a negative event in order to avoid cognitive dissonance (Renn, 1990). Furthermore, the change in attitudes due to a negative shock is assumed to balance back to its initial equilibrium in the long run to keep the predominant attitude (Festinger, 1957). This post-shock adjustment towards the a-priori level should be stronger for people holding a-priori positive attitudes towards nuclear power than for people who express a-priori uncommitted feelings, hence, hold stronger negatively laden emotional images. I assume that proponents of nuclear power are not free of doubts and hold positively as well as negatively laden images of nuclear power (compare, Midden and Verplanken, 1990; Peters and Slovic, 1996; Visschers and Siegrist, 2013; Siegrist and Visschers, 2013; Siegrist and Sütterlin, 2014).

To summarize, I conclude that social groups who are known to have the tendency to hold stronger positive or negative attitudes towards nuclear power react differently to new information of a nuclear accident. People holding skeptical views, who perceive nuclear power as dangerous, will not change their opinion, and the negative event only confirms their view. People who hold a-priori positive emotional images of nuclear power will only change their attitude to a minor degree, to avoid cognitive dissonance. Indecisive people holding skeptical as well as positive images of nuclear power are those most likely to change their attitudes towards a more skeptical risk perception of nuclear power, perceive nuclear power as more dangerous after a nuclear accident.

7.2.3. Social structure of nuclear risk perception

I will very briefly summarize the expected effect of sociodemographic factors and will point to expected differences between social subgroups. For a detailed explanation see Section 5 and the theoretical section in the first empirical chapter (Section 6). Women are expected to show higher levels of nuclear risk perception compared to men. It is assumed that different socialization processes form women's attitudes creating a greater awareness for potential risk for a family's and community's health (Brody, 1984; Solomon et al., 1989; Greenberg and Schneider, 1995; Forbes and Sells, 1997; Davidson and Freudenburg, 1996; Chodorow, 1978). Men tend to express more knowledge about a risk and base their judgments on economic benefits and expected likelihoods of nuclear power; also holding strong values that are based on a concepts of traditional masculinity. Furthermore men are more prone to avoid cognitive dissonance (Kuklinski et al., 1982; Costa-Font et al., 2008; Reardon and Govender, 2013; Kahan et al., 2007). I furthermore assume that people who expect themselves to be more knowledgeable, because of higher levels of education, are less likely to express lower levels of nuclear risk perception. Age is expected to be an important influential factor on nuclear risk perception. Older people are expected to hold more traditional values and are better integrated within the existing economic and social system, trying to maintain and to improve existing social and economical order by ignoring environmental threats. As a result, older people tend to express lower levels of risk perception compared to younger cohorts (Grendstad and Selle, 2000; Peters and Slovic, 1996; George and Southwell, 1986; Van Liere and Dunlap, 1980; Malkis and Grasmick, 1977; Carstensen et al., 1999). Trust in people as well as in political institutions should result in lower levels of nuclear risk perception because nuclear risk is a global phenomenon and cannot be directly experienced most of the time (Freudenburg, 1993; Flynn et al., 1992; Fox and Firebaugh, 1992; Slovic, 1999; Bella, 1987; Slovic, 1993; Rayner and Cantor, 1987; Viklund, 2003; Löfstedt, 2005, 2003; Breakwell, 2007). People with a higher socio economic status, such as higher levels of income or higher levels of education within a social group should also express lower levels of risk perception. People with higher economic status are expected to maintain their status and have higher levels of economic concerns. Better educated people perceive themselves as comparably more knowledgeable, and support the existing knowledge structure which created their status. Nuclear power is a symbol of economic and technological growth, and a symbol of scientific virtue. The technology can be perceived as an important driver for prosperity and economic growth for a society (Stout-Wiegand and Trent, 1983).

The immediate change in nuclear risk perception after a nuclear accident should be more pronounced with people who a-priori hold lower levels of nuclear risk perception: males, older people, people with higher levels of trust in political institutions, and people with higher socio-economic status (i.e. higher educational and income levels). Since people with a-priori already high levels of nuclear risk perception are not expected to update their attitudes or negatively laden images towards nuclear power much. I assume that the immediate effect of a nuclear accident will narrow the gap of nuclear risk perception within a society and I will observe a convergence of nuclear risk perception.

To sum up our theoretical model I derive the following hypotheses for the overall levels of nuclear risk perception (main effects) and the expected changes within each group due to the nuclear accident (interaction effect):

H1 Women have a higher risk perception than men (main effect).

H2 Men react stronger to the Fukushima accident because their initial subjective expectation of the likelihood of an event is lower compared to women (interaction effect).

H3 Younger people have a higher risk perception than older people because of a less conservative value structure (main effect).

H4 Compared to older people, younger people react less to the accident (interaction effect).

H5 Individuals with high socioeconomic status (SES), measured in education levels and income class, before Fukushima have lower risk perceptions because their expected knowledge about an accident is higher and they are able to compensate direct negative outcomes of a nuclear accident easier (main effect).

H6 I don't expect an interaction effect between SES and the Fukushima accident, as long as the negative consequences of a nuclear accident are not changing but only the likelihood of nuclear accidents.

H7 Individuals with high trust (in politics/technology) have lower risk perceptions (main effect).

H8 The interaction effect between trust and the Fukushima accident is unclear because there is an endogeneity problem. I expect that people who after the nuclear accident still trust in political authorities are people who are strongly activating their value-belief system and hierarchical worldviews to avoid cognitive dissonance. Compared to pre-Fukushima accident levels nuclear risk perception is expected not to change or rather decrease for that sub-population.

7.3. Data and methods

The following part of this chapter is a co-working project with Dr. Rudolf Farys and Dr. Thomas Häussler, both from the University of Bern, Switzerland. Rudolf Farys did perform the statistical analysis and produced the graphs using the statistical software `R`, interpreted the results, and helped structure the research question.[77] Thomas Häussler added helpful comments for interpreting the results and clarifying underlying assumptions. The research idea is to use the Fukushima Daiichi nuclear accident of March 11, 2011 as a natural experiment. The incident randomly produced two groups that can be compared using statistical methods. The first group is made of individuals who express their risk perception before March 11, 2011. In an experimental setting this group is called the control group. The second group are individuals expressing their nuclear risk perception after March 11, 2011. This group received new information of a nuclear accident and is called the treatment group. Since the Fukushima Daiichi accident was an unexpected event and independent of a data generating process, we assumed that individuals are randomly divided into a control and treatment group. We use data from the International Social Survey Programme (ISSP) 2010, Environmental Module III (ISSP, 2012). This survey is a representative sample of at least 1,000 individuals in more than 30 countries (mostly OECD countries). The national samples are conducted at different time points. Each ISSP member country can chose their own survey period, resulting in a heterogeneous sample over time unless the survey period is within a reasonable time frame and follows ISSP's conducting standards. For this reason, the separate national samples used in this analysis were conducted in 2010 and 2011. The exact date of the interviews are reported in the data set. This allows to select national samples with respondents interviews before March 11, 2011 and after the accident (see Figure 15).

The variable of interest for our analyses is a five-scale item for the question: *And do you think that nuclear power stations are...* with answer categories ranging from *extremely dangerous for the environment* (1) to *not dangerous at all for the environment*

[77] Rudolf Farys and I presented the results at a colloquium at the University of Zurich, Switzerland (date: March 12, 2014, title: "Do we change our opinion after the bang? Autopsy of a Fukushima effect.") as well as at the International Sociological Association (ISA) conference in Yokohama, Japan (date: July 18, 2014, title: "Nuclear Risk Perception before and after Fukushima.").

(5). We reversed the scale and interpreted high values to indicate people with a high risk perception. The question specifically asks how dangerous respondents perceive nuclear power plants for the environment. I think that the question is a valid instrument for testing individual's nuclear risk perception. I assume that respondents answering the question do not differ explicitly between risk for humans and risk for the environment, since humans as well as all living beings are part of the entire environment.

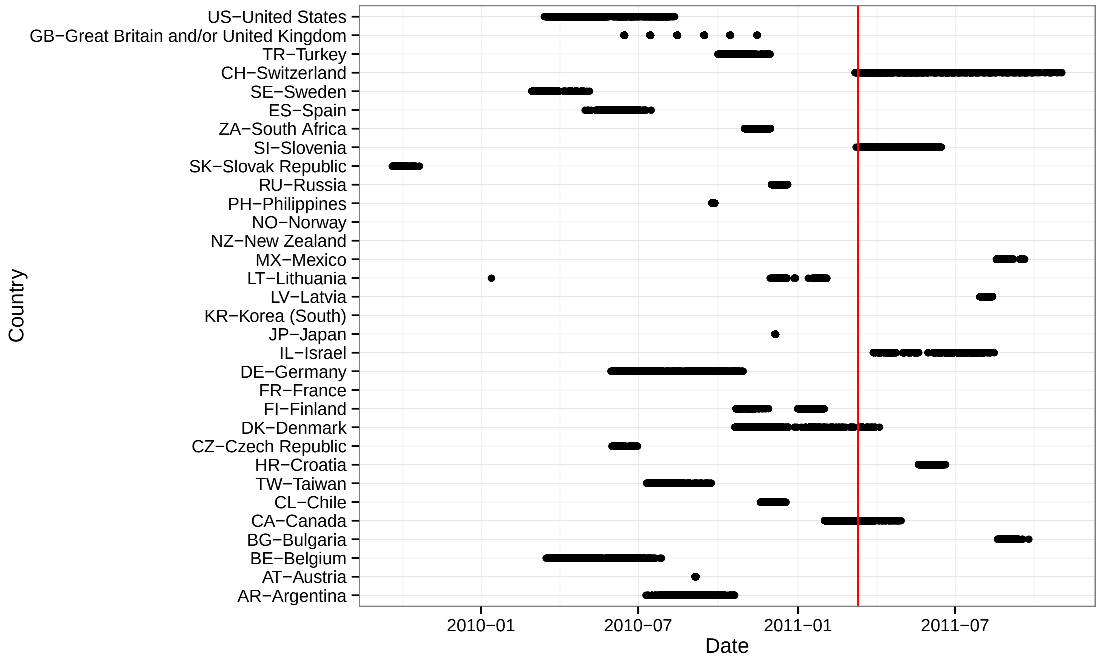


Figure 15: Survey period of the ISSP 2010's 32 member countries. Red line indicates the date of the Fukushima Daiichi nuclear accident on March 11, 2011 (source: ISSP 2010, own calculation).

Since the ISSP 2010 contains both, interviews before and after the Fukushima Daiichi accident, the data allows us to identify a causal effect of the nuclear accident on nuclear risk perception. We identify the causal effect using two statistical approaches: (1) a fixed effects estimator (FE), and (2) a regression discontinuity design (RDD). The two methods rely on slightly different underlying assumptions and identification strategies, so using both methods is an appropriate means to test the robustness of the expected causal effect.

Natural experiment

Related to the nuclear accident, we wish to emphasize some basic assumptions related to the information structure before and after the accident. We assume that none of the people interviewed a-priori could anticipate the exact time and location of the Fukushima accident. We furthermore assume that after the accident, all of the respondents received the same information, i.e. that a major nuclear accident happened at the Fukushima Daiichi nuclear power plant on March 11, 2011. We furthermore assume that the individuals were randomly assigned to the two groups in the natural experiment. Because of the data structure, we want to address a few critical remarks. First, as can be seen in Figure 15) data are clustered by countries. When comparing individuals before and after the Fukushima Daiichi accident, we are comparing individuals within different countries. The problem is that countries can differ strongly with regard to their baseline risk perception leading to a bias when estimating the expected 'Fukushima effect'. Second, it is possible that within a country sample some people systematically are interviewed later in the survey period. For example, people employed full time respond later to an interview request were and interviewed at the end of the interview period. We address these problems using two different identification strategies: the fixed effects approach to control for unobserved but systematic country differences; and the regression discontinuity design to give respondents interviewed closer to the accident more weight.

Fixed effects model

A fixed effects (FE) model is performed to address the problem of systematic differences in nuclear risk perception between countries. Since each country's average risk perception is assumed to differ greatly, we need to perform a procedure to make it possible to compare individuals within different countries. A country fixed effects model demeans all model variables for each country, therefore eliminating all unobserved heterogeneity that is time-constant between countries. This enables the possibility of comparing individual risk perception across countries. Yet, because of the split in a group of individuals that were interviewed before or after March 11, 2011, the dataset could still be biased by variables that vary over time and country. It is also the case that most of the countries do not show any variation within the treatment variable (nuclear accident) because a country's survey period entirely took place before or after the Fukushima Daiichi accident. In this case, it is not possible to split the sample into a control and treatment group. Therefore we only chose countries where the survey period took place before and after the accident to identify the treatment effect. These countries are Denmark, Switzerland, Slovenia, and Canada. With the fixed effect design, it is possible to perform a fixed effects model with interaction effects for time and country to derive the effects for the control and treatment group. The effects for each independent variable before and after the accident are then identified and compared to test whether the gap of nuclear risk perception is widening or narrowing due to the new information of a nuclear accident. We also can identify the variables which changed significantly. For the fixed effects analysis, we only use data from respondents in Denmark, Switzerland, and Slovenia who were interviewed in March 2011 ($n = 638$). For Canada, the interview date is only reported per month because the survey was not conducted in personal interviews, but by sending questionnaires to the respondents. Since for the Canadian respondents who answered in

March, we cannot identify the date of their response, all Canadian respondents are not used in the fixed effects design.

Regression discontinuity design

The regression discontinuity design (RDD), as a second approach for identifying the causal effect of a nuclear accident on people's nuclear risk perception, addresses a potential bias resulting from the time-dimension by giving people more weight who expressed their nuclear risk perception closer to the accident's date. The identification strategy is to define a cut point to split the sample into a control and a treatment group. In the RDD model, an assignment variable is defined, which is a metric variable with a fixed cut point, the point of discontinuity. In our case, the assignment variable is time, measured in days, and the cut-point is March 11, 2011. The basic assumption of the RDD model is that people who are closer to the cut-point are more comparable and, hence, get more weight. With this procedure, we avoid having the observed discontinuity as an artifact due to a biased sampling process and not due to the event itself. The reduction of possible cases to only cases that are around the cut-point leads to results that are less biased compared to OLS regression designs, such as the fixed effects model that simply compares all cased before and after the cut-point with equal weights. To identify the accident effect in our RDD model we use a bandwidth of 30 days, using only interviews that are not in far distance from the discontinuity. In the RDD model we use all cases from the three countries overlapping the nuclear accident (Denmark, Switzerland, and Slovenia) and also Canadian cases in February and April[78] In the RDD model we also use cases from countries that do not overlap March 11, 2011, but are close to the discontinuity; these countries are Israel, Finland, and Lithuania. The total sample size is $n = 7,681$.

We use the FE and the RDD models to test the above mentioned hypotheses because each model has its own advantages. The RDD allows respondents who responded closer to the accident more weight, therefore represent the actual effect of the accident more accurately. With the RDD design, the possibility of a systematic bias due to the date of the interview within the national sample is then controlled. The disadvantage of the RDD design is that only a bivariate analysis of separate effects of categorical dummy variables is possible. The FE-model allows for modeling various metric scaled variables and estimates interactions in an multiple regression design, but it does not control for possible biases due to the time since the accident.

[78] Since we do not know the exact day of the response we assign the responses randomly to any of the possible days in February and March.

7.4. Results

7.4.1. Results of fixed effects model

The results of the fixed effects (FE) model are summarized and graphically displayed in Figure 16 (for a table with coefficients see Table 11 in the Appendix). The dependent variable is operationalized on a five point Likert scale, allowing respondents to evaluate nuclear power in five categories from (1) 'not at all dangerous' to (5) 'extremely dangerous' for the environment. Thus, the range of the scale is from 1 to 5. Gender is a binary coded dummy variable with male respondents as reference category. The results indicate that ceteris paribus women on average report 0.32 scale points higher levels of nuclear risk perception than male respondents before the Fukushima Daiichi accident (H1 confirmed). After the accident, the difference remained but the observed difference of 0.25 scale points was significantly lower compared to the pre Fukushima levels. The results indicate a consolidation of nuclear risk perception among the observed male and female cases (H2 confirmed). The effect of age (measured in years) is negatively related to nuclear risk perception (-0.04 scale-points per year) before the Fukushima accident (H3 confirmed). After the accident the coefficient increases significantly by 0.03 scale points, remaining slightly negative (H4 confirmed). Education is a categorical scaled variable with 'no formal education' as reference category and 'university degree' as highest possible level of formal education. Before the accident, people holding a university degree show significant lower levels of nuclear risk perception compared to respondents in the reference category, indicating a negative effect of education on nuclear risk perception (H5 confirmed). The observed negative trend remains, indicating no effect of the accident on nuclear risk perception. Larger standard errors after the accident lead to wider confidence intervals resulting in no significant education effect on nuclear risk perception. Individual's household income has a negative effect on nuclear risk perception before and after the nuclear accident. The accident did not change this effect. Summarizing the effect of education and income we cannot observe a change in nuclear risk perception in either directions. Hence, socio-economic status has in its tendency to negatively effect nuclear risk perception (H6 confirmed). This effect is not particularly pronounced and does not change in the case of the Fukushima accident. General trust is operationalized as an additive index of two 5-point Likert scaled variables asking if people (a) can be trusted and (b) if people try to be fair. Political trust is measured in a 5-point Likert scale asking whether people agree that people in government can be trusted most of the time. There is an observed inverse relationship of general trust and political trust on nuclear risk perception before the accident (H7 confirmed).

The results of our analysis show that people[79] who prior to the accident expressed higher levels of general as well as political trust, also express lower levels of nuclear risk perception. This effect remains even though the effect on one hand becomes weaker for

[79] Correctly speaking we are not referring to individuals but social sub-groups when speaking of people, because we do not have a longitudinal sample but a cross-section sample.

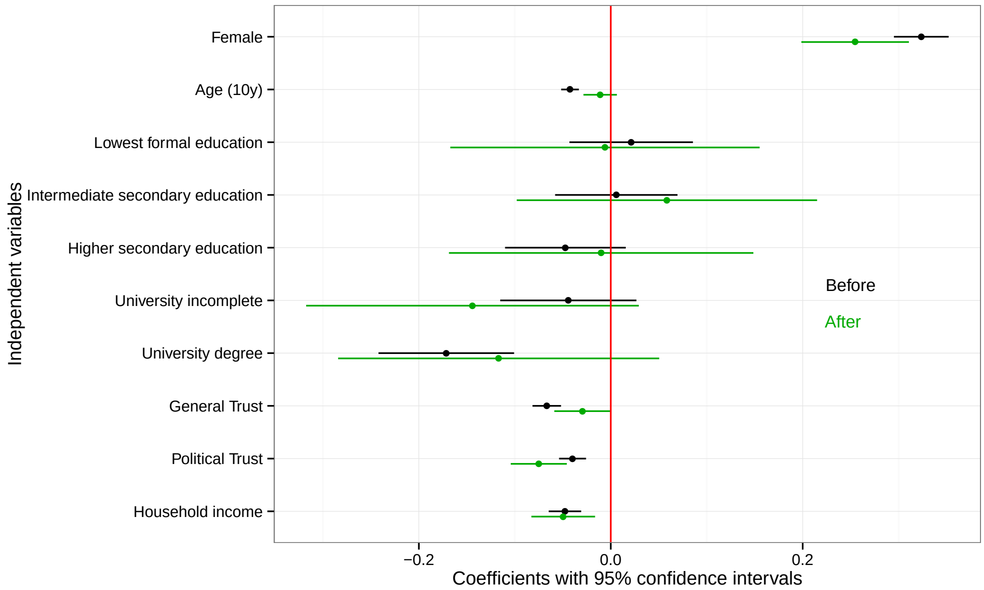


Figure 16: Estimated coefficients of control and treatment groups for the fixed effects (FE) model with 95 % confidence intervals (source: ISSP 2010, own calculation).

general trust, a convergence of nuclear risk perception, and on the other hand becomes stronger for political trust, a polarization of nuclear risk perception. Hypothesis 8 is confirmed when focusing only on the effect of political trust on nuclear risk perception. We do not know to what degree the effect of trust is a problem of endogeneity since we can also assume that nuclear risk perception prior to an accident has an influence on trust in political institutions and actors. The accident can also change people's levels of trust in political authorities. People with high levels of nuclear risk perception might be changing their levels of trust negatively, proponents of nuclear power might perceive an accident as a proof of their trust in political authorities. For us, the effect should be interpreted with caution since the data structure does not allow to control for endogeneity.

7.4.2. Results of regression discontinuity design

Figure 17 shows the result for the regression discontinuity design (RDD) model for the immediate effect of the accident, using observations within a time span of 30 days to derive the discontinuity. The horizontal $X-$axis represents the estimated change in scale points of nuclear risk perception due to the accident, displaying the estimators and their 95 %-confidence intervals. The results are also displayed in Table 12 in the Appendix. The overall effect of the accident is significantly different from zero, indicating an increase in nuclear risk perception by 0.44 scale points. The results of the immediate effect show that men reacted significantly to the accident, while women did not (see also for a detailed visualization of the differences in the discontinuity between man and women Figure 18 in the Appendix). Older people above the median age of 47 years changed their risk perception after the accident, while younger people did not show a discontinuity in nuclear risk perception (see also Figure 19 for more details in the Appendix). Less educated people reacted to the nuclear accident showing higher levels of risk perception, while the group of better educated people did not change their risk perception (Figure 20, Appendix). A significant change in different income groups cannot be observed (Figure 21, Appendix). People expressing high levels of general trust after the accident showed significantly lower levels of nuclear risk perception, while people expressing high levels of political trust did not change significantly their nuclear risk perception (Figure 22, Appendix).

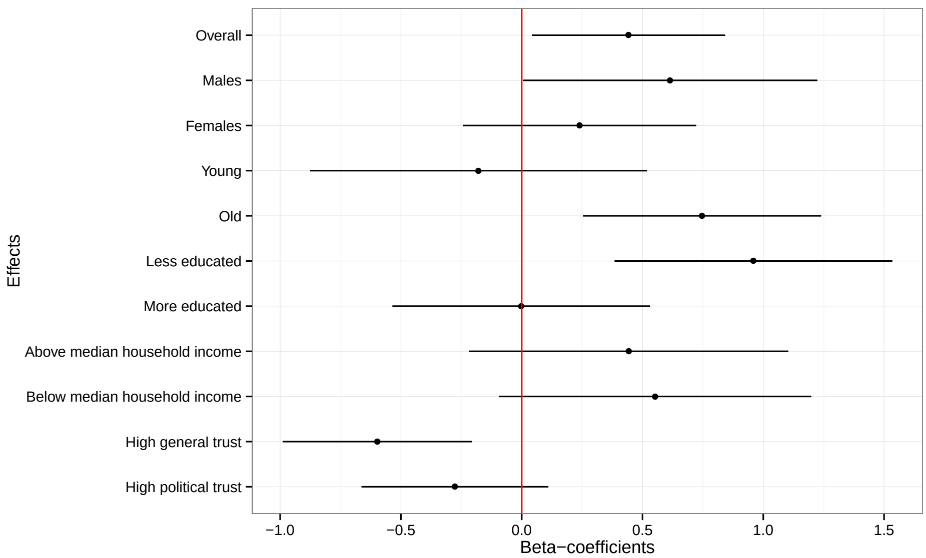


Figure 17: Estimated effect of the nuclear accident (with 95 % confidence intervals) using a regression discontinuity design (RDD) and a bandwidth of 30 days (source: ISSP 2010, own calculation)

To summarize the results of the FE and RDD design: we can show that social factors systematically influence individual's nuclear risk perception before and after the Fukushima Daiichi accident (compare for example results from the fixed effects model in Figure 16). Furthermore, we cannot reject the hypothesis that after the Fukushima accident people's risk perception consolidates and is more homogenized, at least for the time period examined in the RDD model. Women in all models show higher levels of nuclear risk perception. This effect is less pronounced after the accident, indicating that men's change in nuclear risk perception is more pronounced than for women. Also older people, people who express general trust and to some degree better educated people adjust their nuclear risk perception, resulting in a more homogenized distribution of nuclear risk perception within the examined population.

7.5. Conclusion

In this paper we argue, that a sudden incident of a nuclear accident narrows the observed gap in public nuclear risk perception. The results show that, in case of the Fukushima Daiichi nuclear accident on March 11, 2011, public nuclear risk perception becomes more homogeneous resulting in higher levels of nuclear risk perception. Not surprisingly, nuclear power is perceived as more dangerous on average by people interviewed after the accident. This change in nuclear risk perception is not consistent among all of the people observed. Social groups who prior to the accident showed lower risk perception, such as males or older people, expressed comparably more nuclear risk perception after the accident, therefore, narrowed the risk perception gap. This effect holds for most of the subgroups we observed in our analyses. Only in the case of the subgroup of people who expressed great political trust before and after the accident, the inverse effect of trust and nuclear risk perception increased leading to larger differences in risk perception. The gap between men and women also narrowed, indicating that men updated their risk perception more and are getting closer to the on average higher risk perception level women already held. This indicates that nuclear risk perception is not changing linearly. This means that people who a-priori to the nuclear accident expressed a high level of nuclear risk perception cannot to the same degree express a higher level of nuclear risk perception compared to respondents who a-priori expressed moderate levels of risk perception.[80]

The results indicate, as discussed in the theoretical section, that people who hold both, positive as well as negative images of nuclear power, are more likely to change their evaluation of nuclear power than individuals who before the nuclear accident held a very skeptical view on nuclear power. Skepticism might result in doubts and, therefore, in a higher likelihood to adapt nuclear risk evaluation in the case of a massive accident. From my point of view, the results support the concept of the affect heuristic (Slovic et al., 2007), a concept that is based on the assumption that people judge risky events, activities, and situations upon positively or negatively laden images of that risk. The degree to which a change in nuclear risk perception actually changes people's support for nuclear power (compare for example Siegrist et al., 2014) cannot be examined with the given data structure. Empirical studies indicate that the change of risk perception due to a sudden shock of an accident is not permanent but declines again (Renn, 1990). Even though change in risk perception is not permanent it is evident that nuclear power bears the potential to increase society's risk levels to some degree over a period of time. It seems to be strong enough to undermine people's political trust. The shock of

[80] We also performed a simulation to simulate a possible ceiling effect with the data. The simulation shows that the observed differences do not indicate a ceiling effect.

an accident can lead to permanent changes within the social structure of a society or community. Germany's experience with nuclear power is an example how both, lack in political authorities and the increased level of nuclear risk perception after the Fukushima accident resulted in the manifestation of the historically grown wish in the country to stop nuclear power production in Germany for ever (compare for example Goebel et al., 2015).

I cannot prove how people are using heuristics to derive their risk judgment of nuclear power. Nevertheless, I think heuristics play an important role in human's risk evaluation. I also think that heuristics are an underlying driver explaining why we observe differences of nuclear risk perception especially in the cases when people express extreme low or high levels of nuclear risk perception. By evaluating risks, heuristics are ignoring to a great degree all available information and allowing individuals, depending on an individual's starting point of information, to only refer to a limited set of options. As I point out in the theoretical section, the same heuristics can lead to extreme cases of perceiving nuclear power as very dangerous or not at all dangerous. Unfortunately, the data does not allow us to test this assumption. The reflections support Ortwin Renn's concept of an integrated framework of risk (Renn, 2008) that locates heuristics on the core of individual's risk judgement process (compare Section 5.6). Heuristics, as I want to emphasize, are not biased or based on erratic human reasoning, as claimed and criticized in literature (Tversky and Kahneman, 1974; Gigerenzer, 1991). The concept of the affect heuristic seems to open the space for new discussions on human's evaluation of risk, at least in the case of nuclear risk perception the results of this cannot reject the theoretical concept.

The study also has its limits. Because of the cross-sectional data structure we compare sub-groups of a control and a treatment group using the event of the Fukushima Daichii accident as the discontinuity date or cut point. We can only assume that the actual country samples are unbiased random samples. We assume that individuals in both groups are comparable. We also do not discuss the role of media and how the information of the accident differs across the population.[81] We assume that the Fukushima Daichii accident was a global event with high media coverage right after the event in all countries that are in the ISSP 2010 and that the information is homogeneously distributes across all people in the sample. Regarding the operationalization of the dependent variable we assume that the single question we use is a valid instrument to measure individual's nuclear risk perception. This means that respondents perceive themselves as part of the environment and do not differentiate between a risk of power plants for human beings and a risk of power plants for nature.

My final remark touches the deeper roots of nuclear power and its associated risk perception within the population. Paul Slovic speaks of risk that can create ripple effects that cross geographical and societal boundaries once a negative event occurs (compare

[81] For a media analysis in the German case see for example (Arlt and Wolling, 2015; Wolling and Arlt, 2014).

for example Slovic, 1987, see also Section 4.2.3). He uses the image of the ripples a stone makes when thrown into a pond. In the case of the nuclear accident of Fukushima, I would go one step further and suggest to speak not of a pond, as an unlimited open space, but of a tea cup, as a limited space.

I see our earth as a tea cup, as a closed system. In this case, a drop of water creates ripples that move outwards to the edges of the cup and simultaneously back to the center. The fear of nuclear power is an empirical fact. The fear of nuclear power is constantly dripping water in the tea cups of nuclear risk perception. So far, the global society has been able to handle this level of nuclear fear. But once in a while, the evidence of a nuclear accident, such as in Fukushima 2011 or before in Chernobyl (1986), or Three Mile Island (1979) pours a massive drop of fear in this tea cup so that the ripples are waving back and forth and the overflow of human reactions cannot be controlled in the cup.

The results of our analysis indicate that the fear of nuclear power is a global phenomenon and that a sudden negative event can increase, at least in the short run, individual's risk perception. I assume that this shock has massive consequences for the inner well being of humans and unexpected consequences for the social and political structures of the global society. Beside for these fears, the use of nuclear power is an empirical fact for nuclear accidents are real and also an empirical fact. The next nuclear accident is likely to happen at any time. The tea pots of fear are filled waiting to be poured in the cups. There will be consequences, of this there is no doubt. The question is where and when will the ripple start to move towards the edges of their tea cups and spill over. Maybe there is a peaceful way to cool down and empty the tea pots of nuclear power to give those voices all over the world a meaning which perceive nuclear power as very dangerous.

7.6. Appendix

Table of fixed effects model

Coefficient	Main before	SE	Main after	SE	Interaction	SE
Female	0.324	(0.0146)	0.255	(0.0286)	-0.0684*	(0.0342)
Age (1y)	-0.0425	(0.0047)	-0.011	(0.0089)	0.0316**	(0.0107)
Lowest formal education	0.213	(0.0328)	-0.006	(0.0822)	-0.0244	(0.1078)
Intermediate secondary education	0.576	(0.0325)	0.058	(0.0799)	0.0560	(0.1048)
Higher secondary education	0.473	(0.0321)	-0.010	(0.0809)	0.0404	(0.1049)
University incomplete	0.443	(0.0362)	-0.144	(0.0884)	-0.0965	(0.1119)
University degree	0.171	(0.0361)	-0.117	(0.0854)	0.0577	(0.1093)
General Trust	0.667	(0.0076)	-0.029	(0.0151)	0.0376*	(0.0179)
Political Trust	0.398	(0.0072)	-0.075	(0.0149)	-0.0351*	(0.0174)
Household income	0.478	(0.0086)	-0.050	(0.0169)	-0.0018	(0.0187)

$^{**}p < 0.01$, $^{*}p < 0.05$

Table 11: Fixed Effects model. Display of relevant coefficients and interaction effects for respondents for the control ('Main before') and treatment group ('Main after') (n = 396 (remaining cases of n = 638 from the Danish, Swiss, and Slovenian March 2011 samples)). Complete model contains country as well as time dummies for all ISSP countries.

Table and figures of regression discontinuity design

A summarizing table and figures of the separate effects of the RDD model are displayed below.

Coefficient	Estimate	SE	95 % CI (low)	95 % CI (up)
Overall	0.442*	(0.204)	0.0427	0.842
Males	0.614*	(0.311)	0.00464	1.224
Females	0.240	(0.246)	-0.242	0.722
Young	-0.179	(0.356)	-0.876	0.518
Old	0.747*	(0.252)	0.254	1.240
Less educated	0.959*	(0.293)	0.384	1.534
More educated	-0.00195	(0.272)	-0.535	0.531
Above median household income	0.443	(0.337)	-0.217	1.104
Below median household income	0.553	(0.330)	-0.0935	1.199
High levels general trust	-0.597*	(0.2001)	-0.990	-0.205
High levels political trust	-0.276	(0.197)	-0.663	0.111

$^{*}p < 0.05$: at least significant at the 5 % significance level

Table 12: Summary of RDD regression effects with standard errors (SE) and lower and upper limits of the 95 % confidence intervals. The bandwidth of the model is 30 days.

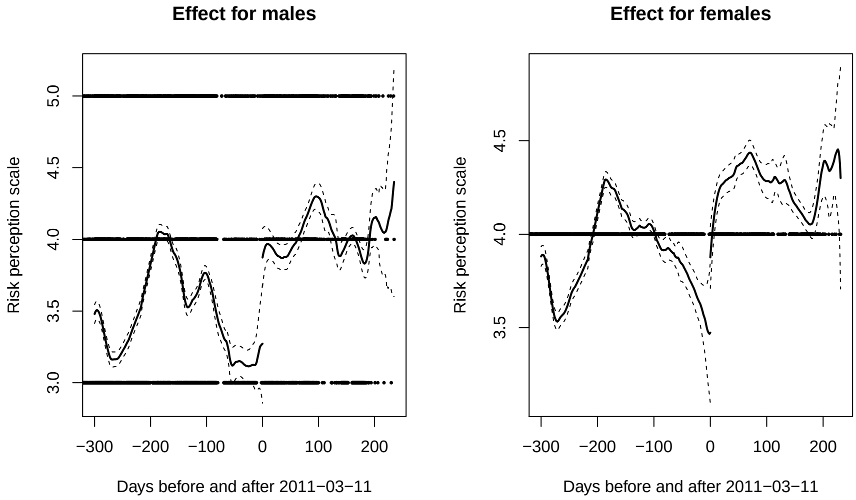


Figure 18: Discontinuity of male and female respondents in the RDD model (source: ISSP 2010, own calculation).

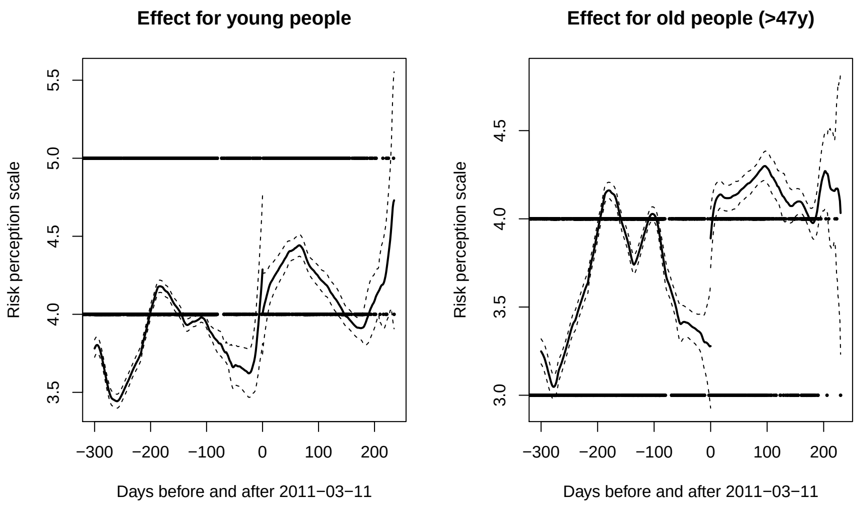


Figure 19: Discontinuity of older and younger people (split at the median age of 47) in the RDD model (source: ISSP 2010, own calculation).

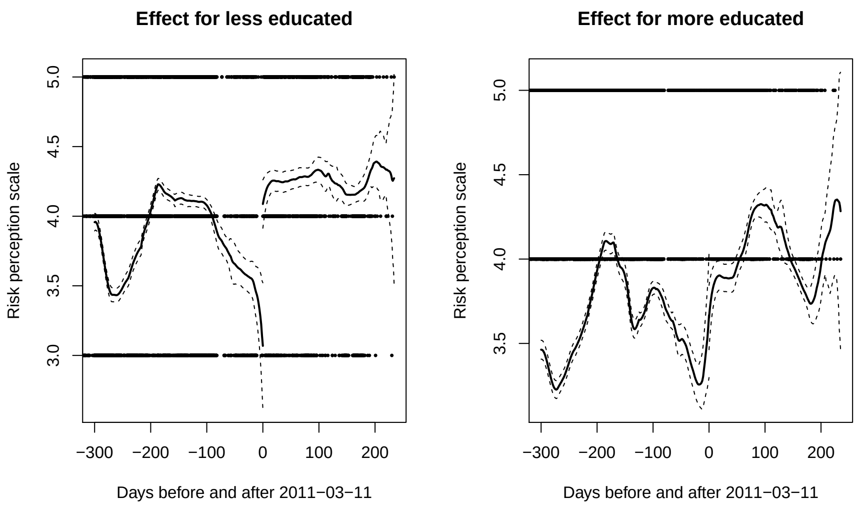


Figure 20: Discontinuity for lesser and better educated people in the RDD model (source: ISSP 2010, own calculation).

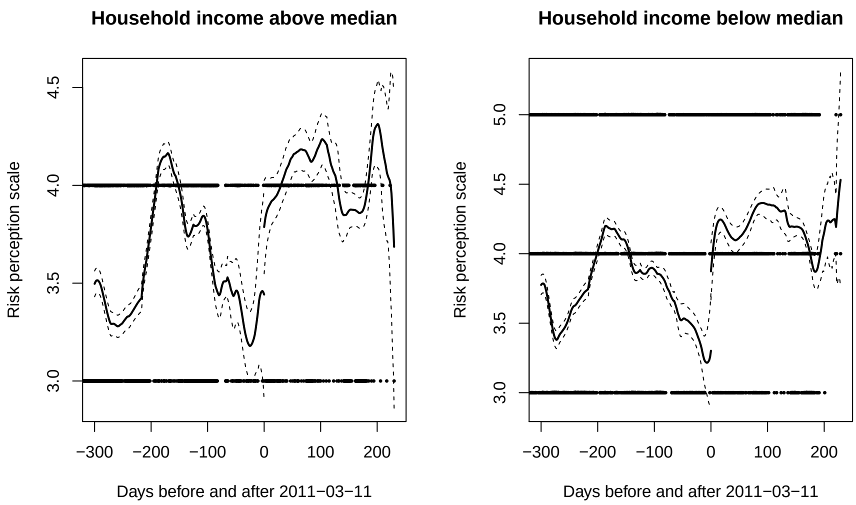


Figure 21: Discontinuity for lower and higher income people in the RDD model (source: ISSP 2010, own calculation).

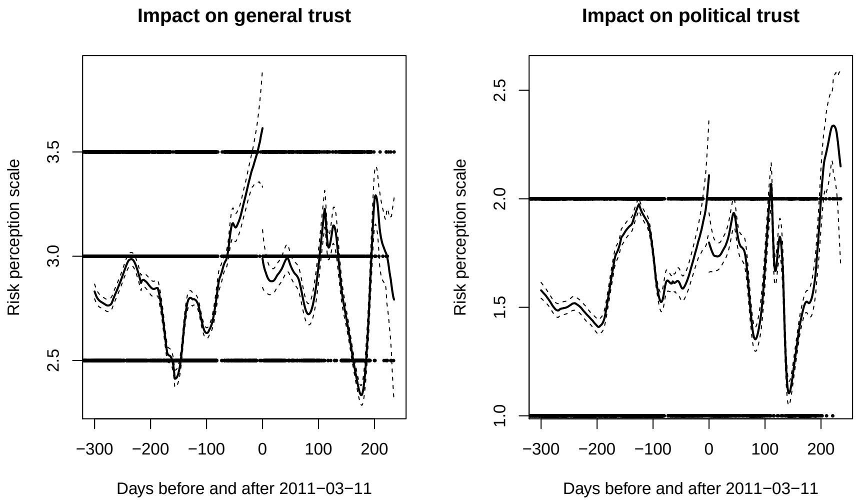


Figure 22: Discontinuity for people with general trust and people with political trust in the RDD model (source: ISSP 2010, own calculation).

8. Empirical Research III: Environmental attitudes after Fukushima: A cross-national comparison of nuclear risk perception and environmental concern after the Fukushima Daiichi accident

Acknowledgements: The German version of this chapter "Der Einfluss der Reaktorkatastrophe auf das nukleare Risikobewusstsein und das allgemeine Umweltbewusstsein in der Bevölkerung" (Vogl, 2014) is a chapter in an edited volume "Fukushima und die Folgen. Medienberichterstattung, Öffentliche Meinung, Politische Konsequenzen" (Wolling and Arlt, 2014). This translation differs only with minor deviations from the German version. The results are identical.

8.1. Introduction

On Friday March 11, 2011 at 2:47 pm, Japan standard time, the Tohoku seaquake took place. As a result of the seaquake, 136 kilometers (85 miles) east of Japanese's coastline, 50 minutes later, a catastrophic tsunami hit the coastline, devastating costal areas and severely damaging the Fukushima Daiichi nuclear power plant. The natural catastrophe ended up not only being a humanitarian, ecological, and economical catastrophe for the region and the country, but also a technological disaster. In three units of the Fukushima Daiichi nuclear power plant, the worst possible nuclear accident of a core melt down happened. On April 12, 2011, in their International Nuclear Event Scale (INES), the International Atomic Energy Agency (IAEA) ranked the Fukushima Daiichi nuclear accident in the highest category (category 7) as major accident.[82] The Tohoku seaquake was more than a local shock. It also revealed individual fears of nuclear power around the world. Anti-nuclear protests and clear repercussions took place immediately after the accident in geographically distant countries. For instance, German and Swiss policy makers decided to pass laws for a nuclear phase out ('Atomausstieg') by 2022 in Germany and by 2034 in Switzerland. Countries such as Belgium, Austria, and Japan also passed laws to regulate stopping nuclear power in the future.

For citizens around the world, the nuclear disaster was an unexpected shock. The accident revealed that nuclear power's peaceful use can change immediately and causes severe damage for the local environment and communities, as well as having unexpected long-term consequences for citizens and the eco-system. A nuclear accident is an unexpected event and from a technical point of view, the expected likelihood of a nuclear accident is very low. As I explained in Section 2.4.6 only a combination of independent

[82] Source: `https://www.iaea.org/newscenter/news/fukushima-nuclear-accident-update-log-15` (accessed July 16, 2016). Before the Fukushima Daiichi disaster only the Chernobyl disaster (Ukraine) on April 26, 1986 has been ranked as major accident.

and virtually unlikely incidences lead to a nuclear catastrophe. Not only unexpected environmental factors, such as the tsunami, but also human error in operating the nuclear power units, can lead to such combination of events ending in a mayor nuclear accident (Perrow, 1999). The two major nuclear accidents of Chernobyl and Fukushima provide empirical evidence that independent of its expected likelihood an controllable a core melt down within a nuclear power unit is possible. Nuclear power provides cheap and clean energy but is also a technology bearing a catastrophic potential for humans and nature. As a result, the benefits and risks of nuclear power are distributed heterogeneously among citizens. The question of how nuclear risk perception differs within the population is a relevant question, especially after the Fukushima Daiichi nuclear accident.

In this chapter I ask to what degree the Fukuhshima Daiichi nuclear accident substantially changed individual's nuclear risk perception. Furthermore, similar as in the two previous empirical chapters (Section 6 and Section 7), I evaluate how nuclear risk perception and socio-demographic factors, as well as value based attitudes are related. In addition to my previous research, I compare whether the independent factors are related differently when regressed, first with nuclear risk perception and secondly with an index of general environmental concern. Nuclear risk perception is an important aspect in individual's decision whether to accept or oppose nuclear power (Siegrist et al., 2005; Siegrist and Visschers, 2013). Furthermore, people's behavior, such as support for pro-environmental policies, also depends on how changes in the environment are perceived as threats for personal health (Fransson and Gärling, 1999). Hence, analyzing whether a sudden and rare event of an accident is only a temporary phenomenon or whether it can change individual's nuclear risk perception for a longer period of time is a relevant question for policy makers responsible for the well being of their community.

In this chapter, nuclear risk perception is defined as the perceived danger of nuclear power stations for the environment. The processing of perceived information about nuclear power plants results in a judgment and evaluation nuclear power's dangerous potential (compare for a general definition of risk perception (Renn, 2008, 98); see also Section 7.2 in this dissertation). The main research focus is on socio-demographic factors that correlate with and are assumed to influence nuclear risk perception on an individual level. Particularly, I want to examine which subgroups in society perceive on average nuclear technology as less or more dangerous. Furthermore, I want to know if certain values result in lower levels of nuclear risk perception. For example, people's trust in national governments can shape individual's nuclear risk perception. It is possible that a nuclear accident leads to an erosion in trust and in order to regain credibility, national governments need to take political measures, such as a nuclear phase out bill, to gain trust. As previously mentioned, I am also interested in the question of how nuclear risk perception and environmental concern are differently influenced or related by individual socio-demographic factors and attitudes.

This chapter is structured in five parts. In the second part, I discuss the concept of risk perception and environmental concern. I also discuss the effect of socio-demographic factors and attitudes. Information about the data I use, the statistical method as well as the operationalization of the chosen variables are described in the third part. The results of the analyses are described in the fourth part. In the final part, I recapitulate the research questions and discuss the empirical results, address the limitations of my research, and point to further research questions.

8.2. Environmental concern and nuclear risk perception

Due to the emerging awareness of global climate change and the need to reduce CO_2 emissions on the planet, acceptance of nuclear power has gained new relevance in public discourse. Compared to coal, gas, or oil, nuclear power is supposed to be a clean source of energy able to reduce a country's CO_2 emissions.[83] However, there are uncertain aspects of nuclear technology, such as nuclear waste disposal, unpredictable nuclear accidents, and the existence of the military nuclear arsenal that counter balance these aspects.

Nuclear risk perception contains a specific thematic aspect of an environmental problem, the perceived potential threat of nuclear technology, therefore differing in its scope from a broader concept of environmental concern. Environmental concern is defined as "the degree to which people are aware of problems regarding the environment and support efforts to solve them and/or indicate a willingness to contribute personally to their solution" (Dunlap and Jones, 2002, 485). This definition indicates that environmental concern is comprised of several aspects or thematic indicators: firstly, environmental concern has a cognitive component, indicating that an individual is aware of an environmental problem; secondly, a conative component expresses individual's willingness to contribute to solve environmental problems; thirdly, also a emotional component is sometimes mentioned in literature (Maloney et al., 1975; Maloney and Ward, 1973). General environmental concern is operationalized to measure individual's overall attitudes towards environmental problems (Dunlap and Jones, 2002; Xiao and Dunlap, 2007). Respondents are asked to evaluate their attitudes towards environment and are not asked to judge attitudes towards a specific environmental problem, such as global climate change, nuclear technology, or genetically modified food.

Because of its general definition, there is not one standard measure to operationalize environmental concern. The Diekmann-Preisendörfer-scale (Diekmann and Preisendörfer, 2001) is a measure that uses nine questions to capture the above mentioned three components of environmental concern. Related to this scale, different measures have been used in national or international surveys, such as the 'Environmental Consciousness in Germany' study ('Umweltbewusstseinsstudie in Deutschland') (Preisendörfer, 1999), the 'Swiss Environmental Survey 2007' ('Der Schweizer Umweltsurvey 2007') (Diekmann et al., 2009), as well as in the International Social Survey Programme's

[83] Perry and Weinberg points out that the use of existing resources of uranium, burned by nuclear fission will only marginally contribute to reduce the amount of CO_2 emissions in the global atmosphere (Perry and Weinberg, 2001).

(ISSP) Environmental Modules in 1993, 2000, 2010 (Franzen and Vogl, 2013c,a; Franzen and Meyer, 2010). Different scales to operationalize environmental concern are used in cross-national comparative studies using data from the ISSP or the World Values Survey (WVS) (Marquart-Pyatt, 2008, 2012; Gelissen, 2007; Dunlap and York, 2008).

One important aspect of this chapter is to evaluate how socio-economic factors are related to both indicators, environmental concern and nuclear risk perception. Compare Section 5 for an explanation of individual and contextual factors influencing nuclear risk perception, as well as Van Liere and Dunlap (1980) to explain the social basis of environmental concern. The question emerges as to whether the relationship can be expected to differ between both indicators. Economic well being is assumed to influence positively environmental concern. According to the affluence hypothesis (Baumol and Oates, 1979; Field and Field, 2009) an intact and healthy environment can be perceived as a good, people are demanding more if people or a society becomes more affluent. Inglehart's postmaterialism hypothesis (Inglehart, 1988, 1990, 1995, 1997; Dietz, 2015) also assumes a positive correlation between wealth and people's environmental concern. Different from the affluence hypothesis which assumes a direct effect of wealth on environmental concern, the postmaterialism hypothesis expects affluence to affect environmental concern indirectly through a change in individual's value structure. In an economically advanced society, greater awareness for environmental issues as well as higher willingness to contribute to improve the environment is driven by a value system prioritizing postmaterialistic values, such as ecological stability, the quality of life, or the right for free speech, over materialistic values, such as economic and social security and stability. From the affluence as well from the postmaterialistic approach can be concluded that more affluent people are more aware of environmental problems and more willing to contribute to improving the environment. People who grew up and were socialized in an economically better developed period, such as younger people or people who gained higher levels of education and higher socio economic status during their life, are assumed to have developed more postmaterialistic values and express higher levels of environmental concern. The assumed positive relationship of affluence and environmental concern is supported by empirical studies (Franzen and Vogl, 2013b,c), even though the effect differs depending on the measures of environmental concern (Marquart-Pyatt, 2012).

For nuclear risk perception it is assumed that, in contrast to environmental concern, different mechanisms influence individual's ability to evaluate nuclear power's risk for the environment. Nature can be perceived as a valuable good and people express a great willingness to protect the environment, at the same time they can perceive nuclear power as not dangerous or not as a hazardous threat for their quality of life or their local community. Pampel (2011) emphasizes that the perceived knowledge of environmental or technological hazards is a potential explanatory factor for individual's nuclear risk perception. Empirical studies support the knowledge approach, indicating that better educated people as well as people with higher income also express lower levels of nuclear risk perception (Greenberg, 2009; Greenberg and Truelove, 2011; Whitfield et al., 2009).

The exact mechanism remains unclear because a higher educational degree cannot be solely understood to increase risk perception. It is possible that beside the direct effect of knowledge on risk perception, education also indirectly influences risk perception through higher levels of trust in scientific evidence and technological development, as well as in political and economic authorities that manage and regulate high risk technologies.[84] Since the evaluation of nuclear risk is a complex information processing process, it can be assumed that individuals perceive nuclear power as more dangerous if they feel that they have only minor or diffuse knowledge about environmental problems and its possible solutions and, therefore, an ambiguous knowledge base to evaluate a risk.

People perceiving themselves as politically left oriented are assumed to express more altruistic values and collectivistic worldviews and express higher levels of environmental concern, as well as nuclear risk perception. Furthermore, people holding a left-wing political orientation perceive political regulation for business as well as individual actors as an appropriate means to solve environmental problems (Costa-Font et al., 2008; Neumayer, 2004; Heath and Gifford, 2006; Whitfield et al., 2009). Research also indicates that women express more concerns regarding ecological problems and health aspects in their life and within their community; women also perceive nuclear power as more dangerous than men (Dunlap and Jones, 2002; Xiao and McCright, 2007; Boholm, 1998; Davidson and Freudenburg, 1996). The overall effect of age is assumed to negatively affect attitudes towards the environment and nuclear risks (Nawrotzki, 2012). I assume that higher levels of environmental concern as well as for risk perception can be observed for younger people who want to protect their natural environment, since they have a longer life expectancy than older people. Younger people also formed their values and environmental attitudes with the knowledge of Chernobyl's nuclear accident in 1986. Environmental concern, as well as nuclear risk perception should be lower for older people whose values were developed before the issues of sustainable development and environmental problems became more prominent on the political discourse.

Trust in people, based on principles such as fairness and reciprocity, is assumed to effect environmental concern positively. Environmental problems, understood as common good problems are easier to solve when people trust each other and avoid free riding. Individual's environmental concern, hence, the willingness to contribute to solve environmental problems should increase if someone trusts that other people are also contributing with similar efforts to preserve the common good (Meyer and Liebe, 2010; Liebe et al., 2011). High levels of trust in this sense indicate people's convictions to collectively solve collective problems. Also trust in political institutions responsible to govern environmental problems and technological risks should positively effect environmental concern. Particularly in the case of a nuclear accident, political institutions are responsible for protecting the population and for solving a crisis situation. Trust in institutions is the crucial element to maintain and to reestablish the old order and to

[84] Higher levels of education maybe increase the willingness to accept the "Faustian bargain" (Weinberg, 1972, 33), the deal of society and scientific, economic, as well as political stakeholders to provide a beneficial good in return for the additional risks the whole society has to cope with in the future.

maintain the belief that technological problems are controllable. Therefore, it is assumed that people with high levels of trust in political institutions are more likely to express lower levels of nuclear risk perception (Greenberg, 2009; Whitfield et al., 2009).

I also want to examine whether ambiguity affects environmental concern and risk perception. In this context, ambiguity is understood as an individual's uncertainty about the ability to evaluate the decision making process (Ellsberg, 2001). Uncertainty exists due to a lack of information about a problem's or a risk's causes, and a lack of information about its possible solutions in the future. Lack of information should result in higher degrees of uncertainty about the problems and individuals should be less convinced to be able to actually contribute to solve the problem. People expressing higher ambiguity, as I assume, should be expressing lower levels of environmental concern, i.e. lower awareness of environmental problems and lower willingness to solve the problems. An increased uncertainty about someone's own risk evaluation process should result in higher nuclear risk perception.

A major nuclear accident can increase individual's risk perception due to a loss in trust not only in political institutions, but more specifically by losing trust in a society's ability to govern a risk technology safely (compare Section 5.5 and Section 4.2.2). Several reasons and qualitative aspects, such as uncontrollability, unfamiliarity, unavoidability could lead to that change (Slovic et al., 1984). *Firstly*, a nuclear accident is perceived as an unlikely event and from a technical point of view, nuclear power plants are designed and managed so that a major accident should not happen. A major nuclear accident is an example that even the best possible scientific and regulatory efforts are not able to prevent an, as such, unlikely nuclear accident in the future. Awareness of the unavoidability of a major nuclear accident can increase nuclear risk perception. *Secondly*, the rare event of a nuclear accident clearly shows that a nuclear accident has severe and unforeseeable long-term consequences for the environment and social life in the affected region. Accidents in the future will lead to similar scenarios for other areas in the world. Awareness for human solidarity and concern for future generations can lead to a higher risk awareness. *Thirdly*, an accident reveals that beside all existing knowledge, in the case of an unexpected event, there is little knowledge and only limited technological means to control the situation. The Fukushima Daiichi accident is an example of the limited capabilities utility management had in terms of knowledge, technical expertise, and resources to control the catastrophic situation and to protect the affected population. Awareness of the uncontrollability of a nuclear technology, in case of an accident, can increase nuclear risk perception. *Fourthly*, the accident provides evidence that nuclear radiation cannot be perceived with human senses. It also becomes obvious that the scale and the associated health risk of radiation is not intuitively understandable, demonstrating the unfamiliarity with the risk. In case of a health hazard from nuclear technology, people are not able to judge the actual risk they are exposed to on their own, but depend on experts' judgments and the information provided by public authorities. To summarize: the Fukushima Daiichi nuclear accident clearly showed that nuclear technology is uncontrollable in the case of a severe accident. Furthermore, political institutions did not prove themselves as able to provide reliable information about the accident's health risk for the population. Therefore, I assume that due to the Fukushima Daiichi accident, the evaluation of nuclear technology changed substantially in the population and increased individual's nuclear risk perception.

In contrast to nuclear risk perception, the assumption that the accident in Japan is able to substantially change more general environmental attitudes is less plausible. The concept of environmental concern comprises general beliefs about the environment and is shaped by individual's basic value structure based on personal experience and future expectations. Hence, it seems less likely that individuals change their overall attitudes due to a single catastrophic event. Furthermore, the nuclear accident in Japan can be perceived as a single event in a distant place having no direct influence on other global or local environmental problems, such as global climate change, the overuse of natural resources, or the local air and water quality. In the case of the Fukushima Daiichi accident, I do not assume a substantial effect on individual's environmental concern.

To summarize the hypotheses of this chapter I want to state:

Hypothesis 1a: A major nuclear accident increases people's nuclear risk perception. Environmental concern, in contrast, is not affected by the evidence of a nuclear accident.

Hypothesis 1b: A major nuclear accident changes individual's nuclear risk perception substantially. The effect does not diminish over time.

Hypothesis 2: Women express higher levels of nuclear risk perception and higher levels of environmental concern.

Hypothesis 3: Older people express lower levels of nuclear risk perception and environmental concern.

Hypothesis 4: There is an inverse relationship between education and income, indicators of social status, and a person's risk perception. In contrast, there is an expected positive correlation for education and income, indicators of social status, and environmental concern.

Hypothesis 5: Higher levels of trust in political institutions as well as general trust in people is negatively correlated with risk perception, but positively correlated with environmental concern.

Hypothesis 6: People holding more postmaterialistic values show more nuclear risk perception, as well as more environmental concern.

Hypothesis 7: Higher levels of ambiguity, i.e. the uncertainty of someone's own ability to judge environmental problems, results in an increase in risk perception and decreases someone's environmental concern.

8.3. Data and methods

8.3.1. Description of data and operationalization of variables

To test the above mentioned hypotheses, data from the International Social Survey Programme (ISSP) 2010, Environmental Module III (ISSP, 2012)[85] have been used. The countries' survey period was either in 2010 or 2011. Only in Australia, the survey period was in 2012. To compare the overall effect of the accident on nuclear risk perception and environmental concern (Hypothesis 1a), I have used all available data for 26 countries. In my regression analysis, testing all other hypotheses, I only use data from respondents who were interviewed after March 11, 2011, the day of the Fukushima Daiichi accident. For some country samples, I therefore use a fraction of the whole national sample. My samples size for the regression analysis is 10,329 respondents from nine countries (compare Table 13). In all country samples, the same 60 questions of the ISSP's Environmental Module and further socio-demographic variables were conducted.

Table 13: Survey period and sample size for the ISSP after March 11, 2011.

Country	**Survey period** (after March 11, 2011)	**Days of field work** (after March 11, 2011)	**Number of respondents** (after March 11, 2011)
Australia	05/11/2012 – 08/06/2012	88	1,946
Bulgaria	08/19/2011 – 09/24/2011	37	1,003
Denmark	03/14/2011 – 04/05/2011	23	38
Croatia	05/20/2011 – 06/20/2011	32	1,210
Israel	03/21/2011 – 08/15/2011	140	1,216
Latvia	07/30/2011 – 08/13/2011	15	1,000
Mexico	08/18/2011 – 09/19/2011	33	1,637
Switzerland	03/11/2011 – 11/01/2011	236	1,199
Slovenia	03/11/2011 – 06/15/2011	97	1,080
N-total			10,329

Source: ISSP 2010, respondents conducted after March 11, 2011. Date displayed as MM/DD/YYYY.

Nuclear risk perception is operationalized as an index on a five point Likert scale. Respondents are asked to evaluate to what degree nuclear power plants are dangerous for the environment. The scale is made up of five categories from "not dangerous at all for the environment" to "extremely dangerous for the environment", with higher values of the variable expressing higher nuclear risk perception. Furthermore, for a better comparison with the environmental concern index, the original range of the variable from 1 to 5 is transformed in the value range of 0 and 100. *Environmental concern* is operationalized as an index of nine variables that allow respondents to express their judgment on a five point Likert scale (see for a detailed description of the operationalization of the

[85] After the ISSP 1993 and ISSP 2000, the ISSP 2010 is the third module focusing on the environment. The ISSP data are available at the GESIS data base (`http://www.gesis.org/en/issp/home/` (accessed March 8, 2016)).

environmental concern index Franzen and Vogl, 2013b,c). Respondents' answers are added to an index and transformed into a value range of 0 and 100, with higher values indicating higher levels of environmental concern. The index's reliability analysis of all nine variables results in a still acceptable Cronbach's Alpha of 0.69.

To measure a potential *time effect* on both independent variables, days passed since the nuclear accident on March 11, 2011 are counted in a metric variable for each interview date. Higher values of the time variable indicate that, given the new information of the nuclear accident, respondents had more time to update their evaluation of nuclear power's dangerous potential for the environment. Also, socio-demographic variables are tested as potential influential factors on environmental concern and nuclear risk perception. *Gender* is added as independent variable with 'male' as reference category. To model the *age effect* and to control for a potential non-linear inverted U-shaped effect of age, age in years as well as the squared age variable is used in the model. To test the effect of respondents' formal *education*, a variable with five categories is implemented. The categories are: 'no formal education', 'primary education', 'secondary education', 'high school education', and 'university degree'. These categories are integrated in the model as dummy variables with 'no formal education' as reference category. Individual's metric scaled *household income* is z-transformed with mean value of 0 and standard deviation of 1 in order to compare the effect between countries and different currencies. The z-transformed coefficient is interpreted as the change in nuclear risk perception or environmental concern if someone's household income changes one standard deviation.

General *trust in people* is an ordinal index variable operationalized with two variables. The first variable measures whether respondents express trust in other people; the second variable asks whether respondents think that people treat each other fairly. Both questions are conducted on a five point Likert scale evaluating someone's trust on a scale from 'no trust/fairness' to 'trust everyone/perceive everyone as fair'. The additive trust index has a range from 2 to 10. The variable *trust in government* asks on a five point Likert scale to what degree respondents trust a country's government. Both trust variables are operationalized so that higher values express higher levels of trust. Respondents can also express if they prefer postmaterialistic or materialistic values. Interviewees can choose to rate two value aspects out of four suggestions, two of which are postmaterialistic and two of which are materialistic aspects: postmaterialistic value aspects are 'protect freedom of speech' and 'give people more say in government decisions', materialistic value aspects are 'maintain order in nation' and 'fight rising prices'. Respondents can either choose no, one or both postmaterialistic values. The value range of the ordinal variable postmaterialism is between 0 and 2. *Ambiguity* is operationalized as an additive index measuring the degree of uncertainty derived first from the causes of and second from the solutions for environmental problems. For each variable on a five point Likert scale, respondents can express their degree of uncertainty. The range of the variable ambiguity is between 2 and 10, with higher values indicating higher levels of ambiguity.

8.3.2. Statistical methods

To analyze the effects of the previously described independent variables on environmental concern and nuclear risk perception, a fixed effects OLS regression model has been performed. The sample is an ISSP 2010 sub-sample of nine countries using only respondents who were interviewed after March 11, 2011. The fixed effects model measures respondents' deviation from the overall country mean value in order to control for unobservable country heterogeneity.[86] The effect is interpreted as a relative change of the dependent variable within each country, controlling for each country's mean differences.

To compare the overall effect of the Fukushima Daiichi accident I assume an experimental design in the data structure. This allows for the assumption that two random groups, a control and a treatment group, emerged from the Fukushima Daiichi accident (compare also Section 7). The treatment group are respondents, interviewed after March 11, 2011. Since I compare environmental concern's and nuclear risk perception's absolute mean differences, I assume that due to the experimental design, systematic country differences balance each other out. The assumption of a natural experimental design and the random selection of two groups of people in different countries is realistic because there are no systematically biased factors for why a country should decide to conduct their ISSP questionnaire earlier or later. The accident on March 11, 2011 is an unforeseeably random event in the data generating process. Accepting this assumption, a comparison of attitudes between a control and treatment groups without controlling for unobservable country heterogeneity seems plausible.

8.4. Results

The absolute changes of nuclear risk perception and environmental concern after March 11, 2011 are displayed in Figure 23. The results show that nuclear risk perception increased after the Fukushima Daiichi accident whereas the index of environmental concern showed almost no change. The mean index value for nuclear risk perception for respondents prior to the accident is 67 index points and increased for respondents interviewed after the accident to 76 index points; environmental concern's mean index value changed from 49 to 48 index points, indicating no change due to the accident (Hypothesis 1a not rejected).

Figure 24 graphically displays the results of the fixed effects OLS regression model for respondents interviewed after the nuclear accident. The vertical $Y-$axis contains all independent variables of the model, the horizontal $X-$axis displays the effect sizes. For each independent variable, the effects for nuclear risk perception (light gray) and for environmental concern (black) are shown. The point marks the estimated coefficient,

[86] I also could use an OLS model with country dummy variables to obtain similar effects. In this case I prefer the fixed effects OLS regression model.

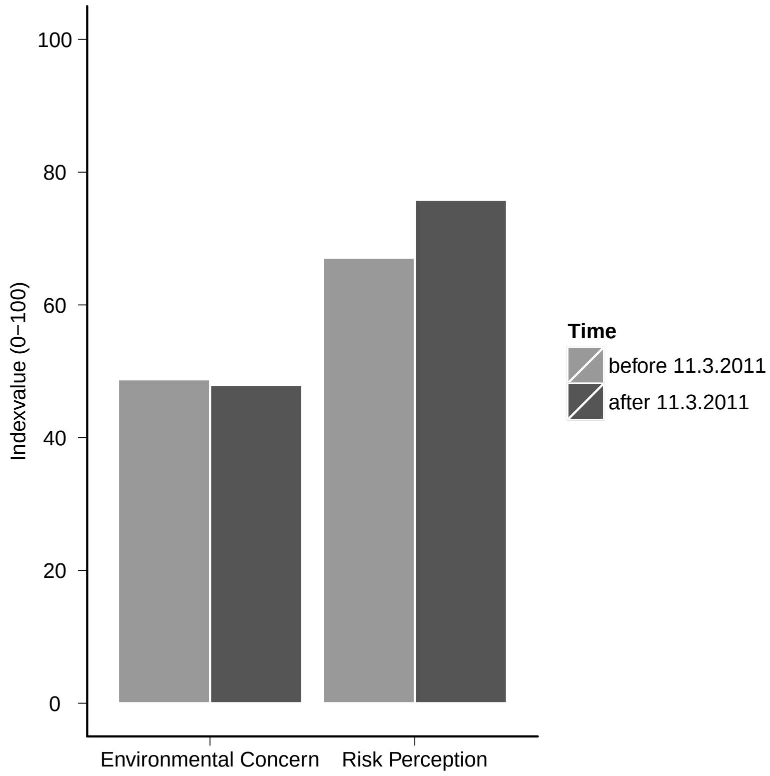


Figure 23: Mean comparison of environmental concern and risk perception before and after March 11, 2011 (source: ISSP 2010, own calculation).

the horizontal line displays each coefficient's 95 %-confidence interval[87]. All coefficients (with t-values) are also shown in Table 14 in the Appendix. At first glance, identical as well as reverse effects of the coefficients on both dependent variables can be seen when comparing the two models.

In the following part, I compare both regression models and their estimated coefficients. The hypothesis that risk perception changed substantially and does not diminish over time cannot be rejected. This holds at least for the observed time of a country's survey period. The effect of time, the difference between date of the Fukushima Daiichi accident and interview date does not differ significantly from zero, even though the coefficient has a negative tendency (compare also the numerical estimate of -0.14 (t-value of -1.00) for every ten days in Table 14). Environmental concern's time estimate has a negative tendency but is not significant on the 5 % significance level (Hypothesis 1b not rejected). Women show higher levels of nuclear risk perception as well as environmental concern (Hypothesis 2 confirmed). The effect of age, for both dependent

[87] If a confidence interval contains the 0 effect, the effect of the independent variable is not significant anymore on the 5 %-significance level.

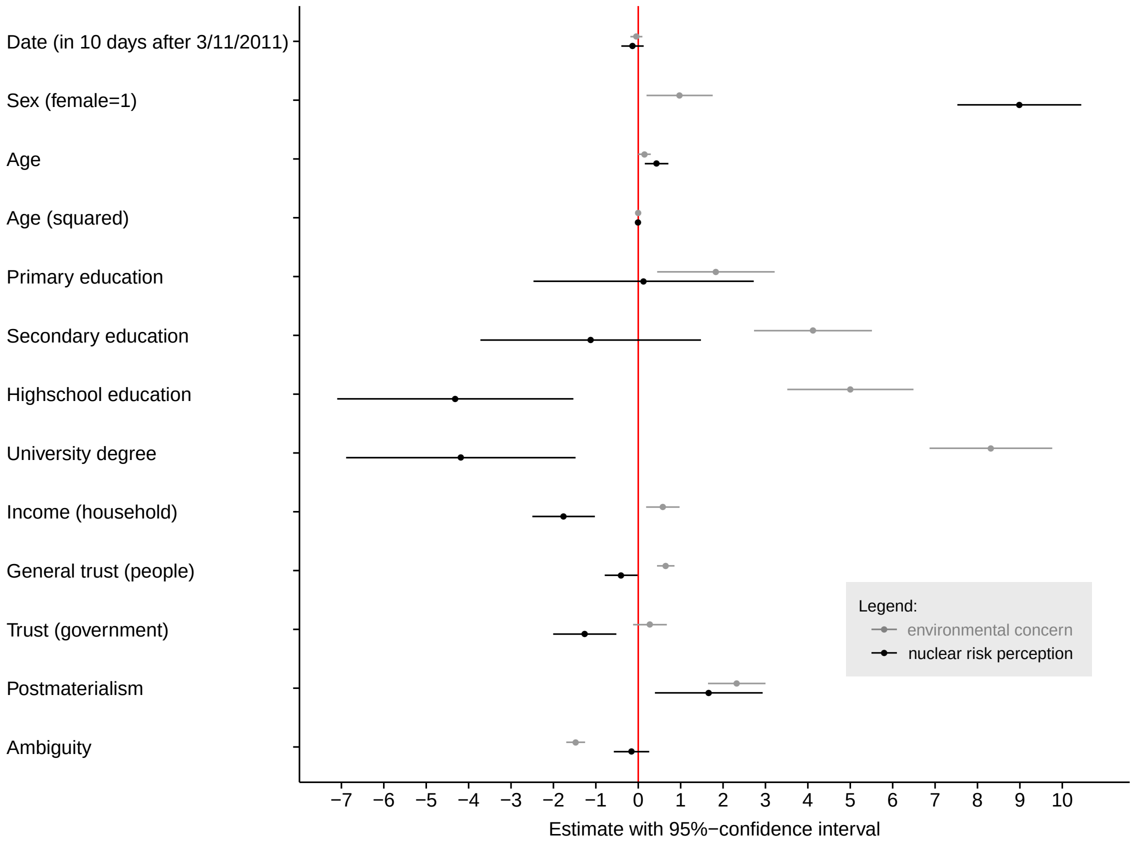


Figure 24: Estimated coefficients of nuclear risk perception and environmental concern. Fixed effects model with 95 % confidence intervals (source: ISSP 2010, own calculation).

variables follows an inverse U-shaped tendency. The inverse U-shaped effect indicates that nuclear risk perception as well as environmental concern increased for younger people. The positive effect is diminishing over time and turning negative for older people (Hypothesis 3 partly confirmed). There is an inverse relationship of educational degree as well as of household income and nuclear risk perception, but not for environmental concern. People with higher education as well as more household income, i.e. people with higher socio-economic status, express lower levels of nuclear risk perception. On the contrary, the relationship of social status is positively related to environmental concern (Hypothesis 4 not rejected). Also both trust variables, individual's trust in people and trust in government, is differently correlated with both independent variables. People who trust more on average, express lower nuclear risk perception and higher environmental concern. The estimated positive effect is not significant for trust in government and environmental concern (Hypothesis 5 partly confirmed). Positive effects on risk perception as well as environmental concern are observed in people who express more postmaterialistic values (Hypothesis 6 confirmed). People expressing higher levels of ambiguity do not show higher levels of nuclear risk perception, but significant lower levels of environmental concern (Hypothesis 7 partly rejected).

8.5. Conclusion

People's evaluation of nuclear risk' dangerous potential increased after the Fukushima Daiichi accident on March 11, 2011. Individuals' nuclear risk perception did not decline as the data show. I can therefore conclude that the sudden shock of the nuclear accident did not diminish after the accident but remained stable over time, at least during the period covered by the data. Even though the data did not control the effect of time in the long run, with the longest period of 236 days in Switzerland, I assume that, on average, the accident substantially sensitized citizens' attitudes towards nuclear power. I also conclude that because of the change in attitudes, in some countries, such as in Germany or Switzerland, voters immediately expressed concerns and policy makers needed to take political measures in order to regain trust in their government and to prove their ability to take responsibility. The nuclear accident and the increased risk perception created ripple effects (Kasperson et al., 1988; Slovic, 1987) affecting policy making processes at distant places (compare also Section 4.2.3 and Section 4.2.8). I cannot prove the assumed link with the given data structure, but the inverse relationship of trust in government and nuclear risk perception seems to be an aspect worth mentioning. Studies (e.g., Whitfield et al., 2009; Siegrist et al., 2014) emphasize that political trust is an important factor in people's perception of nuclear risk and acceptance of nuclear power. This could explain why policy makers in distant European countries passed laws to fade out and to stop nuclear power following the nuclear accident. A possible explanation is that in a crisis situation a passive government loses political trust and voters are more willing to change their political preference structure to support parties expressing anti-nuclear opinions. Because I only can assume the causal relationship between nuclear risk perception and trust, it is possible that an increase in nuclear risk perception results in a decrease in political trust and to gain back citizen's political trust, policy makers decide to take actions against nuclear power. The causal relationship only can be measured with longitudinal data (Siegrist, 2014).

The effect of social status, measured in educational degrees and household incomes, opens the space for further questions and conclusions. On one hand social status is positively related with environmental concern, while on the other it is negatively related to nuclear risk perception. The results suggest that people holding a higher educational level or with higher incomes are more aware of environmental problems and are more willing to contribute to solving environmental problems. According to the affluence hypothesis, this effect is not surprising since richer people are also expected to be more willing to invest in their quality of life. Why then, on the other hand, does this subgroup in the society perceives nuclear risk as less dangerous? A possible explanation is that people with higher status assess nuclear risk from a rational and technical perspective. People with higher education could be more familiar with assessing risks using probabilities and are better trained to differ between a potential and an actual hazard. For example, after the accident people evaluated the likelihood of an additional major nuclear accident within their community based on different information and logical judgment and expected that a new incident was less likely to happen. In addition, it could be the case that people with higher levels of education evaluate the risk of nuclear power in relation to risks from other sources of energy, such as coal, gas or oil, and assess that the number of fatalities from nuclear power worldwide is comparably low compared to fatalities from, for example, coal mining or oil production. From this perspective, nuclear power still has the image of a clean, safe, and cheap source of energy with advantages for nature, society, and economy (Pampel, 2011). Additional studies in the future on nuclear risk perception could examine in more detail which factors influence the observed negative effect of social status and nuclear risk perception.

The results reveal how social factors are related to environmental attitudes as well as nuclear risk perception after a major nuclear accident. The observed effects can be useful for related scientific fields such as communication science. For example, the effects of ambiguity can be used to better understand how uncertainty about the causes of environmental problems and its possible solutions can be influenced by media campaigns. Also, the importance of trust in governmental institutions is a crucial element in people's risk evaluation that can be influenced by risk communication. As described in the Social Amplification of Risk Framework in Section 4.2.8, within their social context individuals as well as institutional actors function as social amplification stations to either strengthen or weaken trust and uncertainty using communicative processes (Kasperson et al., 1988; Kasperson, 2014). Political campaigns can lead to better informed people who are able to evaluate a risk more accurately and build their environmental attitudes based on the best available knowledge. On the other hand, citizens' risk perception and environmental attitudes are also influenced by political or lobby campaigns which aim to spread incorrect information or only selective information focusing on the positive or negative aspects of a technology or environmental problem.

My research could reveal systematic effects regarding how individual's environmental attitudes are related to socio-demographic factors. Nevertheless, the research has its weak points which I want to mention in the hope of improving future research. I also wish to add ideas for new research questions. The time effect has been estimated based on short periods within nine countries. The results would have been more robust if there had been more countries with survey periods of more than six months. To better control for unobserved heterogeneity, it would be necessary to use a longitudinal panel design with individual data before and after the Fukushima accident. Since this data are not available any expressed causal relationship in my work is only an assumption. Furthermore, the fixed effects model could be extended adding country specific explanatory variables in a hierarchical-linear-regression design (e.g. for environmental concern: Franzen and Vogl, 2013c). For example, nuclear risk perception can be influenced by a country's current energy costs or if nuclear power is part of the national energy mix. I have not controlled social or communicative context factors such as the intensity or degree of political debate in the public or media before and after the nuclear accident. Nor did I control the effect of national or international non-governmental organizations dealing with environmental or anti-nuclear topics, as well as economic lobby groups, which are important actors who are able to influence citizens' environmental and technological attitudes. I also did not consider how the Fukushima Daiichi nuclear accident was reported in media. I assumed a homogeneous spread of information across all countries in the sample. In this regard a careful evaluation of media coverage after the Fukushima accident could be useful to detect media-specific influential factors (see for example Arlt and Wolling, 2015).

Finally, I would like to consider how the results can be used to improve research on environmental concern in the field of environmental sociology. One obvious aspect is that the overall level of environmental concern, as measured in an additive index of nine variables, did not change as a result of the accident. This leads to the conclusion that environmental concern is a robust index which is not sensitive to unexpected events such as a nuclear accident. This robust characteristic of environmental concern raises the question of what environmental concern is measuring if even an extreme event, such as the Fukushima Daiichi nuclear accident, is not able to influence the index. I think that environmental concern, as conducted in the ISSP and operationalized here, is a quite general indicator, measuring individual's intension to preserve the environment and to avoid environmental problems. The indicator of environmental concern is not a useful measure or indicator for drawing conclusions on individuals' specific attitudes such as attitudes towards nuclear power. And vice versa, a person who perceives nuclear power a safe technology can express strong attitudes for protecting and improving the environment. This chapter revealed that environmental attitudes are a multi-facetted social element and research subject. It is a useful object for interdisciplinary research and for more comprehensive survey research.

8.6. Appendix

Table 14: Estimated coefficients of nuclear risk perception and environmental concern.

	Nuclear risk perception (Model 1)		**Environmental concern** (Model 2)	
Time dimension				
Interview time since 3/11/2011 (in 10 days)	-0.14	(-1.00)	-0.044	(-0.61)
Socio-demographic variables				
Sex (female=1)	8.99***	(12.1)	0.98*	(2.45)
Age (18-80)	0.43**	(3.05)	0.15	(1.95)
Age (squared)	-0.0050***	(-3.42)	-0.0016*	(-2.04)
Highest educational degree (Ref: no degree)				
Primary education	0.13	(0.096)	1.83**	(2.59)
Intermediate education	-1.12	(-0.85)	4.12***	(5.81)
High school degree	-4.31**	(-3.04)	5.00***	(6.59)
University degree	-4.18**	(-3.03)	8.32***	(11.3)
Household's income (z-standardized)	-1.76***	(-4.68)	0.58**	(2.88)
Individual attitudes				
General trust in people	-0.40*	(-2.05)	0.65***	(6.18)
Trust in government	-1.26***	(-3.32)	0.28	(1.36)
Postmaterialistic value orientation	1.66*	(2.57)	2.32***	(6.72)
Ambiguity	-0.16	(-0.74)	-1.48***	(-13.0)
Constant	71.8***	(15.7)	44.6***	(18.2)
R^2	0.053		0.14	
N	4480		4544	

T-Value in parenthesis, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Fixed effects model in nine countries. R^2 is the explained within country variance.

Part III. The art of change

9. Risk governance

9.1. Social science in risk governance

The "ultimate goal" of risk governance is to design risk communication processes to "reconcile expertise, interests, and public preferences across the cultures within a society and between societies" (Renn and Rohrmann, 2000b, 226). What Renn and Rohrmann describe as the 'ultimate goal' for people doing risk governance is, from their point of view, a complex social act of combining social and factual evidence, information processing and judgement. Risk governance is an act of exchange of all involved interests and voices that are included in the decision making process. As an underlying foundation and basic assumption, it also means to mutually accept different views on risks, including people's risk perception and desire for a save environment to live in and to provide the space for new social life in the future.

In the previous chapters, the empirical evidence and the theoretical approaches from psychology, sociology, and anthropology to explain and evaluate people's risk perception and attitudes, reveal that there is no single approach in social sciences to entirely or completely describe the nature of risk and its perception by humans. As described in the dissertation, from my point of view, risk perception is an open concept to explain how and what people across different cultures, societies, and time points perceive as risks. Renn and Rohrmann (2000b, 224) suggest to understand different approaches in social sciences rather as a single and intertwined entity than as "separate entities." The combination of empirically tested and theoretically derived knowledge, allows risk managers to design risk assessment processes that are sensitive to the broad range of public's views and interests and adoptable by the given power structures.

I think the argument that public's views on risk are biased and based on ignorance, is a tautological argument and ends in an infinite regress: an argument that cannot be rejected and not be proved. There is no *best* risk perception and no *best* approach, no matter how 'technical' or 'soft', to assume a risk's nature. What social-science research allows is to assume that people associate different concerns with different risks. For risk managers, it can be useful to know how individuals in social sub-groups, on average, perceive a risk and how cognitive and affective components, combined with cultural embeddedness form and shape views on risks. A wise risk manager can learn to understand perception forming processes in society. A wise risk manager can furthermore learn to choose the right language and to address risk concerns without facing walls of socially constructed ignorance; or as Renn and Rohrmann present in more technical jargon:

"The core argument here is that risk communication, and indispensable component of risk management, cannot be effective without a comprehensive understanding of how people perceive and evaluate risks, and why risk perception varies so much within a society" (Renn and Rohrmann, 2000b, 225).

The different scientific approaches cannot claim to be overarching and objective. What is common in all of the approaches is the susceptibility to ignorance. The above mentioned integrative framework by Renn and Rohrmann (2000b, 221) reveals a multiplicity of possible positions and perspectives by scientifically approaching the topic of risk (compare e.g. Figure 10 on page 161). What is assumed, accepted, and ignored as a risk differs also across individuals in society. If a risk manager decides to leave the clear cut technical definition of risk, leaving the world of easily calculable and absolutely scaled precise numbers, and enters the vague world of non ordered categories, it becomes clear that what is perceived as a risk by one social sub-group can be without doubts accepted by another social entity.

To come to a decision making process, in a world with "no impartial referee available", social science can help, but is according to Renn and Rohrmann not the finite solution (Renn and Rohrmann, 2000b, 225). Only a dialogical approach can help to find the best available solutions in democratically organized societies (see e.g., Habermas, 1971; Fiorino, 1989; Renn et al., 1993). According to Renn and Rohrmann, science can help design specific communication programs, more or less structured, such as formal hearing, advisory committees, or citizen panels to create trust among people to perceive themselves as an important actor to inform and control in the risk managing process. Social-science research can also enter the arena of risk management and help to "articulate objectives of risk policies" (Renn and Rohrmann, 2000b, 225) that are based on a society's most important values, such as honesty, equity, and trust. By designing such processes, the scientific goal to tell the (unknown) truth will transform in the goal to mediate and monitor the risk communication process and the process of joint decision making.

9.2. Adaptive management

Complex risks and high uncertainties challenge the traditional designs of risk management processes and their ability to cope with risks. Scrutinizing the procedure of how risk where confronted, controlled, and solved by social processes, is also a non-trivial social process. Implementing new processes that are able to adapt to new information bears the risk of loosing existing social trust in risk managing institutions, as Roger Kasperson (2013) remarks when explaining the concept of 'adaptive management' of risks. Adaptive management of risks is an approach that is more suitable for situations with high uncertainties, such as environmental risks, that cannot be managed by the traditional logic or approach of "command-and-control" (Kasperson, 2013, 81). The 'command-and-control' approach follows a vertical way of thinking (or of language) with different steps to first identify a problem and finally to solve the problem. The basic assumption is that risk and uncertainties are quantities that can be measured and understood sufficiently in order to develop exact models and accurately forecast potential outcome and consequences. Based on this assessment, the decision making process, itself based on quantitative standards, is designed to produce the best solution. This process usually follows detailed guidelines.

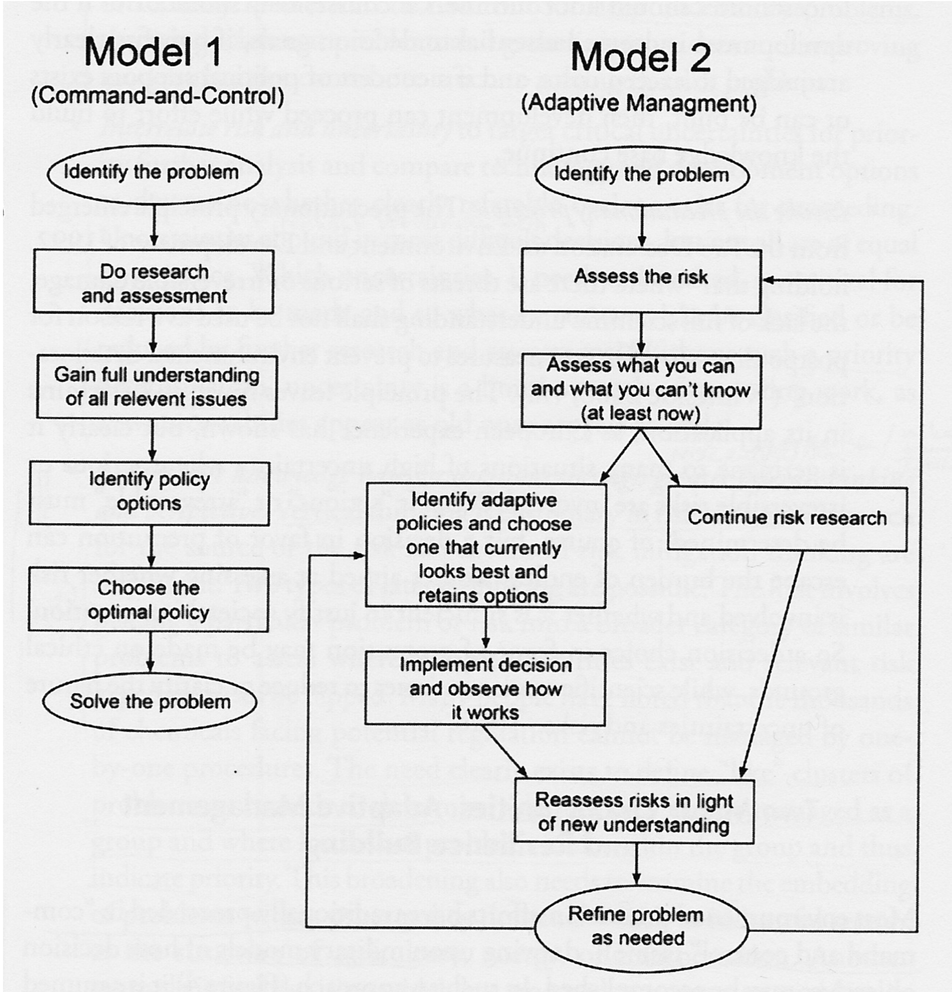
It is not surprising that the linear and vertical command-and-control approach, designed in the 20th century, using the language of the 20th century, is "drawing upon military models of how decision objectives may be accomplished" (Kasperson, 2013, 81). Kasperson uses the example of global climate change or the case of radioactive waste disposal facilities to exemplify that the world is an entity of coupled systems with uncertainty as a predominant factor: "... [in] a kaleidoscope of social, economic, and political institutions, high levels of uncertainty challenge existing assessment methods and familiar decision and management procedures" (Kasperson, 2013, 73). Kasperson questions the "well-honed strategy of "divide and conquer" of positive science" that seems to haven been the standard approach in the scientific community, ignoring the need for more "holistic and integrative assessments" that are able to cope better with the existing ignorance structures in society to form and build a more resilient society (Kasperson, 2013, 74).

Adaptive management is an alternative concept, Kasperson puts forth. This approach provides an alternative logic to irrevocable knowledge claims, control of uncertainty based on logical assumptions, and risk regulation based on vertical thinking. In the case of adaptive management the participants or parties involved in the process accept that deep uncertainty still is a predominant factor.[88]

The acknowledgement of uncertainty and accepting that uncertain knowledge exists, allows social knowledge-structure to grow with the risk in an co-evolutionary process. Collaboration among all parties is an important factor for allowing for mid-term corrections and adaptive management. Lateral thinking, in this case, is an important factor to learn form experience in society with complex risks (compare an example of lateral thinking in the comparison of climate change and terrorism Rosa et al., 2012). It is assumed that the future cannot be accurately predicted and mutual learning is essential to adapt to changes that are to be expected. The logic of learning (c.f., Henry, 2009) is an essential factor. This process also follows the language of "humility" because as Kasperson states: "When uncertainties abound, there is little reason to believe that we will get things right on first try" (Kasperson, 2013, 83). The contrasting strategies for

[88] Kasperson distinguishes between three types of uncertainty: a) aleatory uncertainty, b) model-parameter uncertainty, and c) deep uncertainty, or ignorance or epistemic uncertainty (Kasperson, 2013, 74-75). The later case of deep uncertainties he defines as: "These are uncertainty situations in which the phenomena posing potential threats to human societies are characterized by high levels of ignorance, are still only poorly understood scientifically, and modeling and subjective judgements must substitute extensively for estimates based upon experience with actual events and outcomes, or ethical rules must be formulated to substitute for risk-based judgements" (Kasperson, 2013, 75).

the command-and-control approach as well for the adaptive management approach are displayed in Figure 25 (Kasperson, 2013, 82, Fig. 4).



(Source: Kasperson, 2013, 82, Fig. 4)

Figure 25: Adaptive management and command-and-control management.

The question arises 'How should that be possible?' given the existing institutional structures in our developed societies. How to build a society equipped with institutionalized communication structures that are open to evolutionary learning and collaboration? Kaspersons suggestion is to work on a resilient society (compare Walker and Salt, 2006) that can adapt to changes. The aim is to couple nature, society, and technology and form a system that is dynamic. This would involve a change of social capital, social institutions, and social structures of economy. Resilience, therefore, is not the easy rout to glory: "[i]t is a new basic paradigm for guiding society and the economy, and their relationship with nature, to goals of sustainability and resilience and away from preoccupation with short-term profits and gains" (Kasperson, 2013, 84) – if glory is still a valid concept for society in an uncertain and resilient world.

The author criticizes the existing management institutions of both the private and the public sector as not prepared enough to adapt to changes and not designed to learn (Kasperson, 2013, 84). Therefore, Kasperson lists attributes of how institutions should be, if they do not want to follow a traditional command-and-control logic. The attributes emphasized the need for unobstructed communication and flexible power structures such as: horizontal interaction and information flow, flexible management structures, openness to stakeholder and inter-institutional exchange, learning centers within institutions to learn from past errors, acknowledgement of uncertainties, and a socio-ecological and socio-technical worldview (Kasperson, 2013, 84).

One major step to move from the military logic of regaining control by commanding and controlling to the logic of resilience and adaptive learning, is to understand the concept of change. The idea of learning and adaptation is not to move 'back' to an pre-existing equilibrium state of the world, such as the idea of an absolute truth. In an socio-technical and socio-ecological world the only existing equilibrium, the relevant dynamic is change. The language of this dynamic allows for mistakes and uses them to improve learning. In a world of constant change, experiential learning is not an automatic process that leads to the right decisions. Uncertainty which allows for learning, does not mean that the right conclusions will be drawn upon and right measures will be implemented by all participants at the same time and in the same rhythm. Both, flexibility for adjustments and the space for mistakes should be anticipated (Kasperson, 2013, 86).

Since learning is an art and a social process (Feyerabend, 1984), Kasperson encourages all parties involved in a decision making process to keep vigilance and skepticism as learning tools. This creates a permanent space for questioning long-held assumptions that might hinder the understanding of new developments and not making space for alternative views and lateral thinking. Knowledge in that sense and in line with Popper (Popper, 1959) is a fragile and temporary object, and someone's own view or perspective of the world should always be the object of scrutiny and skepticism. Creating a dialogue of vigilance and skepticism with the inner critical voice keeps the ability to learn alive and vital. Kasperson suggests not trying for "debunking" critics if a "plural process to assessment and decision making" wants to be maintained and encouraged (Kasperson, 2013, 87). The aim is not to control different views and neglect or ignore the views that seem to be wrong. The aim is to keep a balance of views in order to learn from each other's experience.

9.3. Risk governance

In the concept of risk governance, laid out by Rosa and colleagues[89], the "*willingness to learn*" (Rosa et al., 2014, 190) by all participants of a risk evaluation process, independent of its openness or closeness, is a prerequisite for successful dialogue. Further important buttresses are the "*resolution of allegedly* irrational responses" and the "*non-moralization of positions and parties*" (Rosa et al., 2014, 191). The first pillar 'willingness to learn' implies that parties involved in the risk assessment process are willing to accept each other's views not feeling pressured to give up their views and not feeling to pressure other parties to change their preferences and attitudes. Learning involves an ability to recognize and to express in words that various forms of rationality exist (compare Lynn, 1986). Learning furthermore involves recognizing that there are different forms of knowledge existing in this world: very structured forms, such as systematic and analytic knowledge (Rosa, 1998); various structured or unstructured forms of experiential knowledge; and there is folklore wisdom[90] in society, passed through generations (Renn, 2010).

The second pillar 'resolution of allegedly irrational responses' means to "discover the hidden rationality in the argument of the other party" and to accept it (Rosa et al., 2014, 191). This part of a communicative process is independent of the actual issue to solve, it is a process of building mutual trust to understand each other's views and the underlying rationale, as the authors point out. One example is the conflict between experts and laypeople. Laypeople tend to provide anecdotal evidence and report emotional reactions or affective experience. This information can be perceived as irrational by experts who tend to rely on analytical thinking and pre-structured empirical evidence. These views can be perceived as technocratic and simplistic. Accepting the rationale of each other's views helps to extract the relevant information – the elixir – of each view to derive to a healthy decision (Rosa et al., 2014, 191).

The third pillar 'non-moralization of positions and parties' stands for the claim, that all parties involved in a dialogical and deliberative process are committed to refrain from moralizing. The above mentioned healthy decision is a compromise and moral judgements jeopardizes that process. "Moral judgements on positions or persons impede compromise. As soon as parties start to moralize, they cannot make tradeoffs between their allegedly moral position and the other parties' "immoral" position without losing face" (Rosa et al., 2014, 191). Accepting the dignity of own's own and other's moral values is the first principle of a successful dialogue. A second principle is to hold on to the equality principle. The equality principle assures that no party is superior or inferior in their position. Moralizing is also a strategy to pretend to have knowledge. Blaming

[89] In the following part I refer to the chapter on 'Risk Governance' (Rosa et al., 2014, Chapter 10: 170-193)

[90] As an example of how indigenous people in the U.S. and Canada passed their knowledge about 'dangerous' places that should be avoided and respected (now known as places containing high levels of uranium) from generation to generation, see (Biergert and Stolhofer, 1993).

or moralizing others serves to keep up appearances when arguments are weak and there is a lack of available information (Rosa et al., 2014, 191).

The above mentioned process of adaptive management and learning from experience, as well as deliberative participation of all involved stakeholders form the ground for an integrative process to create social processes and strategies to solve today's complex and unknown risks. It could also be a practice to find answers for the expected problems associated with risks. As mentioned, the process of scientific analysis and the process of deliberative democratic participation are important elements, that together, create a space where one can first identify a problem and then derive to a solution based on all available and relevant knowledge.

In their part on 'Risk Governance,' Rosa and colleagues describe their idea of an "Analytic-Deliberative Process"(Rosa et al., 2014, Chapter 10: 170-193). As the first element of the analytic-deliberative process in risk management, the authors refer to knowledge that is systematic and reproducible. This external source of analytic scientific knowledge is an essential element, yet scientific knowledge cannot claim to be the ultimate and only source of relevant knowledge in a risk decision process. Independent of the discourse of what is real or objective scientific knowledge, following the methodological principles of relevance, reliability, and validity can produce knowledge of high quality. Methodological rules are an "important yardstick" for measuring the quality of scientific knowledge (Rosa et al., 2014, 180). The authors invite critical views, mentioning the constructivist's skeptical view on scientific results (Jasanoff, 1999, 1996, 1989; Latour, 1987; Wynne, 1992b). A skeptical view helps to keep vigilance and points to the social construction of knowledge. In contrast to the positivistic or realist view: "[the constructivists] see scientific results as products of specific processes or routines that an elite group of knowledge producers has framed as "objective" and "real," these products are determined by the availability of research routines and instruments, prior knowledge and judgements, and social interests" (Rosa et al., 2014, 180).

Rosa et al. point out that, independent of the debate of whether 'real' is realistic or not, in risk assessment processes scientific knowledge is used as a knowledge base and as an instrument to provide knowledge to reconcile conflicting perspectives. All analytical processes follow almost identical rules and are independent of the "philosophical stance of realism" (Rosa et al., 2014, 180). What can be accepted as valid knowledge depends on the procedure of data collection and the cautious interpretation of the available data, the inter-subjective reproducibility of results, and the compatibility of the theoretical approaches. Even if the methodological and the theoretical approaches enable for the acquisition of knowledge in its best quality, the nature of risk itself quite often evades the possibility of being quantified and put into causal models with empirically proven relationships: "often, only intermediary types of knowledge are available when it comes to assessing and evaluating risks" the authors state (Rosa et al., 2014, 180).

In an analytic-deliberative process, scientific knowledge and competing knowledge claims can be judged upon its validity. Systematically assessing the "relative validity" of each knowledge-building process, by revealing the underlying assumptions, and limits of each claim scientific knowledge, can be useful for decision making processes that deal with problems where almost no empirical evidence is available (Rosa et al., 2014, 181). The authors emphasize that in an analytic-deliberative process all knowledge claims, independent of its scientific nature, ranging from systematic knowledge to experiential knowledge or folkloric wisdom, are a-priori equally important and legitimated to find the best solution for each part of the problem in question (Rosa et al., 2014, 181).

Given different cultures of knowledge and within those cultures, considering the different knowledge claims, a thoughtful process that combines and interacts with all different knowledge claims is important: "The term *deliberate* refers to the style and procedure of decision making without specifying the participants who are invited to deliberate" (Rosa et al., 2014, 181). A deliberate process, the authors continue to summarize, is a process in which each argument is judged independent of status of the participant but by its relative weight according to the relevant pros and cons. Furthermore, the process is not primarily designed or geared for decision making, but aims to exchange arguments and invites all participants to reflect on competing knowledge claims (c.f., Webler, 1999; Renn et al., 1993). Because the decision making process is a process that comes to an agreement, rather than to a decision, the deliberative process is a "style of exchanging arguments" that focuses on the validity of each argument and the quality of each statement and inferences (Rosa et al., 2014, 181).

Rosa and colleagues suggest an approach that combines the idea of integrating laypeople's third-party knowledge into the mostly scientifically dominated risk assessment approach and keeping the spirit of a deliberative approach in the decision making process. The combination of the two is what the authors term "*deliberative democracy*" (Rosa et al., 2014, 182). Following a deliberate style helps to combine different forms of knowledge and knowledge generating processes to form a knowledge base for uncertain, complex, and ambiguous problems. Citizens do not step back when uncertainty enters the risk communication arena and citizens cope with disagreement between various expert's views. What citizens often miss is the "integrity" to be accepted with all views, when invited into an expert arena (De Marchi and Ravetz, 1999, 756). Deliberative democracy also integrates concerns of groups relying on the feedback of affected groups. One important strength of deliberate democracy is to create a common understanding through *empathy.* Once a common moral ground is created through empathy, the deliberative process is able to create new options and solutions through a creative process. New approaches and ideas can be discovered and put in place: "It has the potential to show and document the full scope of ambiguity associated with risk problems and helps to make a society aware of the options, interpretations, and potential actions connected with the issue under investigation" (Rosa et al., 2014, 182).

A deliberative discourse has the advantage of testing the internal consistency of a problem – it "clarifies the problem" (Rosa et al., 2014, 182); it furthermore detects framing effects and assures that the arguments are still in line with the existing knowledge claims; it is also a process that follows accepted norms and values present in the whole of society, not only in accordance with values and norms of a dominant sub-group in society. The overall approach of combining different views is an advantage compared to traditional approaches that happen within accepted norms and values of mutual excluding scientific disciplines, following strict standards of gathering and gaining structured knowledge. The traditional approach ignores the knowledge that is within the public, the feedback and creativity that exists, but cannot be measured with scientific methods such as survey information or focus group analyses (Rosa et al., 2014, 182).

Maybe the greatest advantage is that deliberative processes create agreements among all parties involved, independent of their initial views. This processes also helps empower citizens to participate and to "play their role as active citizens in the various political arenas" (Rosa et al., 2014, 183). Common agreements differ in their level of consensus[91].

The crucial point is to combine the analytic part with the deliberative part in a risk assessment process. The question is how to integrate analytic input, i.e. different forms of information, into an existing deliberative process. One important element of that integrative process is to make all underlying assumptions and scientific conventions transparent, and to be open and vulnerable to skeptical critique. It also enables participants to learn to become experts and active citizens (Klein, 1997). The language and the style of how scientific knowledge and results are presented to the broader public should be considered carefully if experts want to be challenged by public's vigilance: "the assumptions and conditions that may constrain the validity and applicability of the modes should not remain hidden behind the image of exact figures and algorithms" (Rosa et al., 2014, 187). The style of presentation of knowledge is important for transmitting and transforming experts' knowledge to the public.

From my point of view, it is important to recognize that all participants of an analytic-deliberative process are aware that they are in charge and take care of the existing knowledge that exists in society. Their work should aim to improve the quality of that knowledge. Vigilance and skepticism help to reflect and help to detect, through a communicative process, the blind areas of a single perspective. Scientific approaches are a simplified picture of reality, based on accepted procedures and limited knowledge: "Experts need to acknowledge that they act on the basis of cultural expectations (paradigms), professional conventions, sometimes doubtful assumptions, incomplete or conflicting data, and simplified models" (Rosa et al., 2014, 188). I think that any social process which allows for critical reflection of the existing knowledge and knowledge cultures is able to create new ideas and solutions for today's and future's risks.

Rosa et al. put forth five quality criteria to design a self-reflecting process that assures that all knowledge has been reflected and carved out (Rosa et al., 2014, 187-188). The first quality criteria for the available information is "*methodological rigor*." This criteria requires the use of all accepted standards to test all evidence claims for their validity. The second criteria is the criteria of "*comprehensiveness and representativeness*." This

[91] A consensus can be unanimously, a win win situation, it can be a tolerated consensus, a morally superior situation, or a compromise, a situation you can 'live with'.

criteria asks if all of the relevant evidence has been collected and analyzed. The third criteria "*incorporation of all relevant knowledge claims*" asks if all forms of knowledge, i.e. systematic, experiential, local knowledge and expertise, were considered adequately. The fourth criteria questions if all conflicts regarding the provided evidence and modes of validation and presentation were solved and all involved participants accept the given knowledge. The fifth criteria asks whether all participants in the knowledge sharing process perceived and understood the inherent normative judgements as part of the provided evidence. It furthermore asks if that judgements are in line with the existing accepted legal norms and conventions that exists in the society.

It has become clear that risk communication is one of the core elements of risk governance. It can be the key to a successful way of govern risk or, from a skeptical perspective, can be the beginning of social distrust of governmental organizations designed to govern complex risks (van Asselt and Renn, 2011, 439). According to Rosa et al. the term governance refers to a political perspective aimed at providing a non-hierarchical organization structure with no a-priori defined authorities. Collectively binding policy solutions are generated in a deliberative process among all participants of a multi-actor network. It is assumed that the power among all participants is equally distributed. This multi-actor network includes actors from civil society, economy, and governmental institutions. An important element is to draw the attention to the diversity of views, logics, and roles, as Rosa and colleagues point out (Rosa et al., 2014, 153).

The concept of governance in contrast to the traditional idea of regulative and hierarchically structured government authorities can be perceived as an answer to a growing complexity in an interdependent and globalized world, with constant technological change and a growing number of uncertain, complex, and ambiguous risk problems. To call for diverse views to find answers for new challenges seems to be an obvious social tool. An institutionalized integrative risk governance structure can help to create a society that is less vulnerable and more resilient. But risk governance is not a self-fulfilling prophecy itself. It is a process that requires "social learning" to adequately include all available information (van Asselt and Renn, 2011, 440). The non-hierarchical structures also come with the disadvantages such as a fragmented risk governance process, cost intensive evaluation and communication procedures, or a loss of trust and accountability for governmental bodies. Beside the concerns of 'bottling old wine in new bottles', of relabeling existing government procedures without changing the underlying processes, the idea of risk governance bears the ability for adaptation and social learning to create solutions for risk problems that are relevant for all members of society: "It is a dynamic, adaptive learning, and decision-making process of continuous and gradual learning and adjustments that permit prudent handling of complexity, scientific uncertainty, or sociopolitical ambiguity" (Rosa et al., 2014, 156).

An adaptive and integrative risk governance process consists of different components and depends on different resources and institutional means. Klinke and Renn (2012) illustrate that risk governance depends on the institutional means, financial and technical resources, as well as on human resources and social capital (see Figure 26). The authors structure the process of risk governance in several components that are all accompanied by deliberative communicative processes. The components are on the one hand the pre-estimation of a risk, combined with an interdisciplinary risk estimation procedure. The other part comprises the evaluation of a risk and risk management strategies, followed by monitoring and controlling to evaluate the chosen risk management strategies as appropriate for the levels of a risk's complexity, uncertainty, and ambiguity. Once a risk passes the interdisciplinary risk estimation process and is ranked according to its complexity, uncertainty, and ambiguity, strategies to manage a risk can be implemented. Either standard linear risk management procedures, such as quantitative risk assessment and risk-benefit analysis by regulation agencies, can be performed or more complex forms of risk regulation, involving more discourse based management procedures with different social actors to address a risk properly. I will not go into more detail to explain the components of the risk governance process[92]. In the last part of this chapter I will focus on the process of risk communication and participation the – from my point of view – key component of successful risk governance.

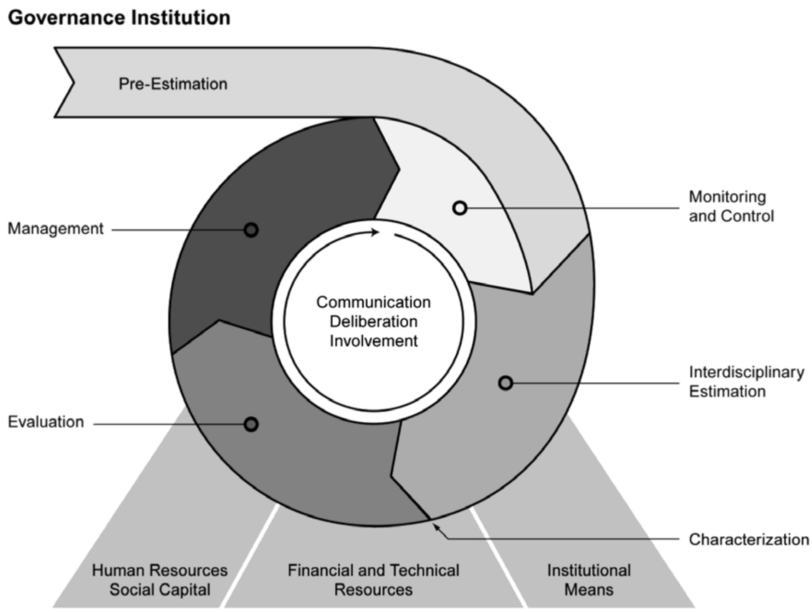


Figure 1. Adaptive and integrative risk governance model.[4]

(Source: Klinke and Renn, 2012, 271, Fig. 1)

Figure 26: Adaptive risk governance.

[92] For a detailed description see Rosa et al. (2014, 156-166) or Klinke and Renn (2012).

9.4. Effective communication

All risk governance processes rely on effective communication at all time and across all levels. “Positively framed, risk communication is at the core of any successful risk governance activity. Negatively framed, a lack of communication destroys risk governance” as Rosa and colleagues (2014, 166) point out. It has become obvious that trying to educate and persuade ‘less’ informed people to make them more knowledgeable – the deficit model of communication – with the intension to make them to understand experts’s knowledge better is not a successful strategy to close the gap between experts’ and public’s opinions (Fischhoff, 1995; Pidgeon et al., 2005). The public is most often well informed, knowledgeable, and not misunderstanding scientific approaches. Effective risk communication even provides the ability to combine experts’ rather abstract expertise and laypeople’s experiential knowledge to get a broader understanding of a complex risk problem (Horlick-Jones et al., 2007). Especially in the case of complex technological risks, such as nuclear power, risk communication is an important mean to build and keep trust between the public and the risk managing agencies; but communication can also destroy trust, if wrong communication strategies are chosen (Whitfield et al., 2009; Figueroa, 2013).

According to Rosa et al., communication in the context of risk governance is understood as an integrative process of policymakers, stakeholders, experts, and the public. Communication, therefore, is defined as “meaningful interaction in which knowledge, experiences, interpretations, concerns, and perspectives are exchanged” (Rosa et al., 2014, 166) and aiming to build trust among all parties involved. A successful communication process, according to the authors, should lead to a shared basis of knowledge and to better and more efficiently govern risk problems. To do that, communication in this sense is not a mere social act, it is to be understood as a technique that allows in an environment of complex, uncertain, and ambiguous information to interact meaningfully and trustfully. Governing risk is a multi-actor approach and, hence, risk communication a method addressed to bring together multiple actors to exchange information.

Communicating is an act of coordinating knowledge within and between different social contexts and among different priorities. Rosa et al. clearly make the point that in the context of risk governance participants share a common “normative position” to include different interests and priorities as a necessary step of a collective decision making process (Rosa et al., 2014, 167). The authors emphasize that inclusion of participants is a problematic process and a challenge for the process of risk governance. Risk governance implies a paradigmatic shift towards risk identification given a set of plural opinions, multiple concerns, and contradicting public values: “[i]nclusion means that actors play a key role in framing (or pre-assessing) the risk” (Rosa et al., 2014, 168).

The method of inclusion always addresses the questions of who should be included, what should be included, and how should it be included. Various forms of involvement can be used to include different knowledge claims, concerns, and public values into a risk assessment process: among others are round tables, open forums, mediation, or mixed advisory committees (Rosa et al., 2014, 168). Successful communication depends on the ability to learn to choose the appropriate methods and strategy of inclusion. The principle of inclusion, as understood by Rosa and colleagues, is a "means to an end" to combine all available information and concerns, to understand what is perceived as a risk by whom and who knows what about that risk (Rosa et al., 2014, 168). The nature of complex, uncertain, and ambiguous risks allows and is asking for a process that incorporates and integrates various sources of knowledge and multiple perspectives. It is also a means to designing and agreeing on a commonly shared decision making rule. This process itself is an important part of a deliberative democratic decision making process that itself is able to strengthen a social community and to make it more resilient to risks that are able to affect the community. The principle of inclusion, the authors conclude, is "intended to support the coproduction of risk knowledge, the coordination of risk evaluation, and the design of risk management" (Rosa et al., 2014, 168).

Inclusion, as normative principle, is an openly designed process that itself follows no strict rules about the degree of inclusion needed by the risk assessment or decision making process. It requires constant learning, adaptation, and differentiation. Inclusion can be a powerful tool for combining different opinions and identifying potential conflicts from the very beginning of the decision-making process. The concept of risk governance provides a platform that allows for such a process, it does not guarantee a successful decision making process. And yet, as Belzer (2001) argues, people should learn to manage their risks and are expected to make their own choices. An active citizen is aware of the responsibility for the decisions needing to be made. Combining citizens' awareness of high responsibility with experts' knowledge is able to create trust within a society, will close the gap among experts' judgements and citizens' – or shall I say laypeople's – perceptions, and at the end will guide all involved decision makers to an commonly accepted decision.

I think, the ability of all actors to learn, grow and change through communicative processes are the key challenges. In the end, in an uncertain environment, everyone will be ruled-out by their own ignorance structures; the presence of risk is an invitation to change and to create an open space, a place to exchange opinions, knowledge, values, and emotions. Uncertainty is not the peril but rather the starting point and a finger-post for constantly creating better communication structures in society. Communicative processes designed to understand the uncertainty structure in society, support to find sustainable solutions for a peaceful coexistence for all future generations.

10. Final chapter: beyond nuclear risk

In my concluding chapter[93] I want to ask: What is the question after the question: ‘How dangerous do you think nuclear power stations are?’? In short: ‘What is beyond nuclear risk perception?’ To answer this question, I summarize four key findings of my dissertation:

1. **Evidence:** the concept of nuclear risk perception is based on empirically observable evidence. There are cognitive as well as social mechanisms for explaining nuclear risks. People in the observed countries are aware of nuclear power’s dangerous consequences for the environment.

2. **Distribution:** nuclear risk perception varies in all analyzed countries and is distributed within a society. The observed differences are not biased observations from one correct way to assess and judge nuclear risk. Nuclear risk perception is a process of intuitive and rational information processing. Within each country there are citizens who express high levels of nuclear risk perception and there are citizens who express low levels of nuclear risk perception, and citizens who perceive nuclear power as somewhat dangerous. The tendency is that people proportionally express higher levels of nuclear risk perception compared to lower levels of risk perception.

3. **Differences:** within a society, nuclear risk perception varies systematically depending on certain socio-demographic factors. The results show that women as well as people with lower socio-economic status express, on average, higher levels of nuclear risk perception. People who express higher levels of trust in the national government, on average, evaluate nuclear power as less dangerous.

4. **Sensitivity:** nuclear risk perception is sensitive to an external shock of a nuclear accident. An accident leads to an increase in nuclear risk perception and a more uniform view on nuclear risk across the public. This changes are more pronounced for subgroups of people who, on average, prior to the accident expressed lower levels of nuclear risk perception.

What is the deeper meaning of the key findings? Risk perception is a social phenomenon and the awareness of a problem is creating a social reality. This holds independent whether the social space is understood as local resilient communities (Jasanoff, 2006) or as a world risk society, as Ulrich Beck claims (Beck, 1992, 1999). It is not the case that all citizens perceive nuclear technology as dangerous. It seems to me that the degree to what nuclear technology is accepted and opposed by citizens is still under negotiation among all involved citizens. It is a local and a global discourse. There is

[93] This chapter is not structured as a summary of my dissertation. For a summary of all chapters please read the Introduction (Section 1). I dedicate that chapter to Ulrich Beck who passed away in January 2015, the time I stated writing on my dissertation.

no excluded other, everybody has its voice in this discourse. The process of evaluating nuclear hazards is on the one hand forming attitudes towards a specific risk on the local level while expressing shared concerns cross-nationally. I agree when Ulrich Beck speaks of "global risk[s]" as the "human condition" (Beck, 2014, 80) of today's world.

Where are citizens' perceptions pointing to? The combined knowledge of all examined societies indicates that nuclear technology has an extremely dangerous potential for the environment. Even though the data of the International Social Survey Programme (ISSP) does not cover all countries, I assume that nuclear concern is a global phenomenon. The patterns of how risk judgment are derived and distributed among the population differ to some degree within countries and between countries. However, in all countries there is a significant proportion of people who perceive nuclear power as dangerous.

For me, the dynamics of nuclear risk perception point in two directions broadening the scope of awareness: 1) nuclear risk perception creates an *outreaching* dynamic crossing the boundaries of a national perception leading towards a global perception of risk; 2) nuclear risk points *inwardly* crossing the boundaries of someone's identity.

I think of the outreaching or embracing momentum of nuclear risk perception first. A belief that this momentum is able to break the boundaries of narrow social spaces and ignorance, creating a global other – a force that is encompassing the most distant social spaces. Nobody is able to be ignored within the cosmopolitan community of awareness. Maybe because the cosmopolitan communities activate at the same time high levels of awareness and ignorance: nuclear risks are a Damocles Sword and a Pandora's Box at the same time (Renn, 1998). Cross-national empirical research on nuclear risk perception (cf, for example Renn and Rohrmann, 2000a; Slovic, 2000a) indicates that nuclear risks are anticipated in quite similar ways in different countries. From Beck's point of view, the shared awareness can have the potential to transform the world: "The sociological point is: if destruction and disaster are anticipated this might produce a compulsion to act. The social construction of a 'real' anticipation of catastrophes can become a social and political force, which transforms the world" (Beck, 2014, 80). Beck in his vision of a cosmopolitan society (compare for example Beck, 2014; Beck and Grande, 2010; Beck, 2011; Aven, 2012b) is convinced that global risks are creating a space of a global togetherness, challenging the concept of exclusive spaces and distant others: "Global risks tear down national boundaries and jumble together the native with the foreign. The distant other is becoming the inclusive other – not through mobility but through risk" (Beck, 2014, 86).

Emotional perception of risk is a very important element of individual's evaluation of risk, as I have clearly argued. With the given data structure I cannot analyze in more detail how emotions are shaping individual's risk perception. However, research indicates that rational analysis as well as emotional reasoning, is the basis for judging a risk (e.g. Finucane et al., 2000a). Neither experts' nor laypeople are free of ignorance. Emotions, according to Beck, open the space to develop new procedures to deal with risks in the future and to include the distant 'other', not in the strict geographical sense, into the discourse (Beck, 2014, 88). Emotions can also have the reverse effect of narrowing the scope of citizen's reflection, leading to new conflicts and new social discourses. Emotions are important for social learning.

Globalized risks, create a global arena of discourses of change: *the art of change* is an open social process. My argumentation points towards the potential for social transformation that is emerging in the discourse of global awareness of nuclear risk. Ulrich Beck speaks of a "cosmopolitan moment" (Beck, 2014, 88)[94] in which the awareness of a global problem creates a space of uncertainty among existing institutionalized actors. This social conflicts in moments of globalized uncertainty have an "enlightenment function" in the eyes of Ulrich Beck (Beck, 2014, 89). The outreaching character of global risks towards the global boundaries of our reflection are stretching our capacities of the existing institutionalized mechanisms towards these boundaries, revealing spaces of ignorance, uncertainty, and irresponsibility. The existing order, the dominant mechanisms of social stability, are destabilized and in this process, opening space to reflect processes for governing global risks.

I think, the moments of global uncertainty, Beck's "cosmopolitan moments", are more than enlightened moments. They simply mean work: work to build or rebuild social institutions able to govern global uncertainties using the means we have today; a deeply emotional process and at the same time opening space to reveal analytically what needs to be done. Listening to all sounds, taken together the knowledge presented in my work, I believe that everything we need to govern risks in the future is already present within our society, within every human being. There is no need to wait for a *better* society or a *better* human being. We have what we need to solve today's problems, today.

The cosmopolitan moment can also be a cosmopolitan moment inside of human beings. In his psychometric framework Paul Slovic and colleagues (1981; 1987) define a risk space with two qualitative dimensions to evaluate risks: (a) dread dimension and (b) unknown dimension. Nuclear risks are scoring high on both dimensions. I think, the unknown and the dread spectrum of human risk awareness is constantly pointing towards a space of inner reflection. What does not work in a context of nuclear technology, for example, is to declare war on an enemy (Bauman, 2009, 2014). This reflection can lead to an increased awareness of how to govern and communicate risks. Research on environmental values points towards the ability of values able to shape collective action and deliberative decision making (Dietz, 2015). Maybe the awareness of nuclear risks enables inner voices to express their wish of a peaceful mutual coexistence of humans on earth. What must start, as I think, is a moment of awe and reverence of life on earth. This change

[94] The whole citation is: "All this is part of the reflexivity generated by risk, by the anticipation of catastrophe. I cannot think of any power inducing, enforcing such a global learning process in such a short period of time. Be careful: not catastrophe does this. The catastrophe is the moment of (total) destruction. The anticipation of catastrophe does it. Manufactured uncertainties, global risks are, highly ambivalent, paradoxically also a moment of hope, of unbelievable opportunities – a cosmopolitan moment." (Beck, 2014, 87–88).

in human reasoning is in conflict with traditional norms and conflicting worldviews (Eisenberg, 2001; Walters, 2003; Ekberg, 2007). McCright and Dunlap conclude that the openness of the reflexive idea also leads to a countermovement of "anti-reflexivity" in societies (McCright and Dunlap, 2010, 126). Since values are a fundamental element in individual's decision making process (Dietz, 2015; Stern et al., 1995; Stern and Dietz, 1994) a sudden change in the global risk structure can lead to unexpected changes in society. To govern risks, from my perspective, the whole social spectrum, from the inner core values to the social institutions and cultural fabrics, needs to work on communicative processes to transform risks within a dynamic of accepted change. Each individual is able to do that, "the historical power of global risk is beyond all the 'saviours"' as Ulrich Beck says (Beck, 2014, 86).

My research on nuclear risk perception aimed to understand different approaches to explain how individuals evaluate risks, in my case nuclear risks. I then turned to the ISSP 2010 data to test how individual's nuclear risk perception is related with socio-demographic factors and, if possible, individual values. The empirical focus aimed to compare cross-national differences in nuclear risk perception before and after the Fukushima Daiichi nuclear accident in March 2011, as well as to show the immediate effect of the Fukushima Daiichi accident on peoples perception on nuclear power. My theoretical work and my empirical analyses have their limitations that hopefully point to further theoretical reflections on that topic and future efforts to provide empirical evidence.

The theoretical limitations of my dissertation are diverse. For instance, I have not reflected the various theoretical approaches in probability theory (cf. for example Aven, 2012b, 2013), nor have I systematically recapitulate the history of nuclear technology and anti-nuclear movements in Section 6. I also am not able to explain in more detail how political power structures are influencing decision making processes (Perrow, 2011). I also do not give much weight to theoretical frameworks in sociology, such as the rational actor paradigm, approaches in critical theory, or Haberma's theory of communicative action (cf, for example Jaeger et al., 2001; Rosa et al., 2014).

The empirical part of this dissertation has its limitations. I use cross-sectional data from the ISSP 2010, therefore cannot test for causal relationships. Research on nuclear risk perception could be improved if surveys are designed as panel data, with individuals being asked continuously about their perception of nuclear risk (Siegrist, 2014). The ISSP only asks one question on nuclear risk perception, which allows only a very general evaluation of individual's nuclear risk perception. The questions asks how dangerous people think nuclear power stations are for the *environment*. I have assumed that this question, especially the term 'environment' comprises the danger for social life as well as for nature. Since human beings and their communities depend on a healthy natural environment, I think my assumption is justified and the question a valid indicator for measuring individual's nuclear risk perception. The lack of specificity of evaluating nuclear risk perception is counterweighted by the advantages of the ISSP to provide representative national samples from over 30 countries to generalize valid results of nuclear risk perception in a cross-national comparison. Many studies on nuclear risk perception have the disadvantage of being non representative ad-hoc samples in selected countries (Rohrmann and Renn, 2000).

Throughout this dissertation, I have tried to grasp the complexity of nuclear risk perception to better understand why different views coexist. To do so, I followed different theoretical approaches to develop a picture of complexity. In my dissertation I did not contribute to work on the theoretical foundation of nuclear risk perception, by systematically comparing different approaches because excellent work already exists in this field[95] (cf, for example Rosa et al., 2014; Renn, 2008). My theoretical restlessness is also caused by the question of how to govern nuclear risk in the future? I believe that nuclear technology is too much of a risk for social beings. As outlined in the introduction, the underlying aim of my work is to learn how to create a world free of nuclear risks. This underlying and covibrating question made me also realize that deep theoretical, historical, technical, and political knowledge is necessary to understand the evaluation process of nuclear risk perception, the evaluation and assessment of uncertainty as well as decision making processes under uncertainty. Risk is a sound, waves of awareness resonating within the boundaries of a social life and changing through exchange of information.

Where does my work point to? Sociological theories (compare Rosa et al., 2014) provide comprehensive knowledge of how individuals evaluate risks, make decisions and act. From my perspective, the interplay of theories, not one single theoretical framework, provides the knowledge not only to explain nuclear risk perception, but also to learn to understand how to govern risks. I encourage inter-sociological as well as interdisciplinary collaboration to share the existing knowledge within the scientific community. I encourage social scientists to share their knowledge with people responsible for governing risks. Neither today's best theory, nor the best empirical work, nor best intended political action can prevent the next nuclear accident. Nuclear accidents have become an empirical evidence in human life on earth in the 21st century. To change this social reality our only option is to turn to wise social actions, based on pure thoughts, respectful words, and honest emphatic action. While still respecting the work of the pioneers of nuclear technology, this also means that banning nuclear technology is one possible step to govern nuclear risks today. I hope my work will serve as inspiration towards developing social foundations for a global society able to govern nuclear risks.

Epilogue

What needs to be done to govern nuclear risk? We need to build social institutions able to govern nuclear risks, as Alwin Weinberg already demanded in 1972 (Weinberg, 1972). The question 'if' society wants the "Faustian Bargain" between "nuclear people" and "society" (Weinberg, 1972, 33) is not relevant. Nuclear technology is a reality of our modern world. What if the society now wants to build social institutions to govern

[95] I am not able to improve this outstanding knowledge, and I do not see a necessity to do so.

this technology? What can society demand in return from 'nuclear people' to build these institutions? Peace! Peace among all nuclear people. Utopia! This utopian wish seems to be ad-hoc and not possible. It is not. History proofed that it is possible. A joint effort between 1942 till 1945 of *national states*, Great Britain and the U.S., *social institutions*, the army, politics, industry, and finance, and *individuals*, such as nuclear scientists, made the Manhattan project possible and created the first nuclear bomb. Similar projects around the world followed that project after World War II. Is it possible to start an Utopian Manhattan Project II to take nuclear technology a step further? Is the next step to institutionalize to govern nuclear risks globally and for future generations? We cannot change problems beyond human's ability to change, but accept and build resilient communities (Jasanoff, 1999). Nuclear technology is not beyond human's ability to change: we can change the need for nuclear technology and can learn to overcome enmity. We can create Utopia. Maybe a moment to reflect upon. The art of change starts within. It begins with a moment of silence – a sound of change. A first step would be deliberative assessment processes which consider different perceptions and views as equally valid (Aven and Zio, 2014).

References

Abelson, Robert P. 1959. "Modes of Resolution of Belief Dilemmas." *The Journal of Conflict Resolution* 3:343–352.

Adorno, Theodor W, Else Frenkel Brunswik, Daniel J Levinson, and Robert Nevitt Sanford. 1950. *The Authoritarian Personality*. New York: Harpers.

Afifi, Walid A and Judith L Weiner. 2004. "Toward a Theory of Motivated Information Management." *Communication Theory* 14:167–190.

Alhakami, Ali Siddiq and Paul Slovic. 1994. "A Psychological Study of the Inverse Relationship Between Perceived Risk and Perceived Benefit." *Risk Analysis* 14:1085–1096.

Arcury, Thomas A, Susan J Scollay, and Timothy P Johnson. 1987. "Sex Differences in Environmental Concern and Knowledge: the Case of Acid Rain." *Sex Roles* 16:463–472–472.

Arlt, Dorothee and Jens Wolling. 2015. "Fukushima Effects in Germany? Changes in Media Coverage and Public Opinion on Nuclear Power." *Public Understanding of Science* .

Arvai, Joseph L, Robin Gregory, and Timothy L McDaniels. 2001. "Testing a Structured Decision Approach: Value-Focused Thinking for Deliberative Risk Communication." *Risk Analysis* 21:1065–1076.

Aven, Terje. 2008. "A Semi-Quantitative Approach to Risk Analysis, as an Alternative to QRAs." *Reliability Engineering & System Safety* 93:790–797.

Aven, Terje. 2010. *Misconceptions of Risk*. Wiley.

Aven, Terje. 2011. "A Risk Concept Applicable for Both Probabilistic and Non-Probabilistic Perspectives." *Safety Science* 49:1080–1086.

Aven, Terje. 2012a. *Foundations of Risk Analysis*. John Wiley & Sons, 2 edition.

Aven, Terje. 2012b. "On the Critique of Beck'S View on Risk and Risk Analysis." *First International Symposium on Mine Safety Science and Engineering 2011* 50:1043–1048.

Aven, Terje. 2013. "On the Meaning of a Black Swan in a Risk Context." *Safety Science* 57 IS -:44–51.

Aven, Terje, Piero Baraldi, Enrico Zio, and Roger Flage. 2014. *Uncertainty in Risk Assessment*. The Representation and Treatment of Uncertainties by Probabilistic and Non-Probabilistic Methods. John Wiley & Sons.

Aven, Terje and Ortwin Renn. 2009. "On Risk Defined as an Event Where the Outcome Is Uncertain." *Journal of Risk Research* 12:1–11.

Aven, Terje, Ortwin Renn, and Eugene A Rosa. 2011. "On the Ontological Status of the Concept of Risk." *Safety Science* 49:1074–1079.

Aven, Terje and Enrico Zio. 2014. "Foundational Issues in Risk Assessment and Risk Management." *Risk Analysis* 34:1164–1172.

Bammer, Gabriele, Michael Smithson, and Goolabri-Group. 2008. "The Nature of Uncertainty." In *Uncertainty and Risk: Multidisciplinary Perspectives*, edited by Gabriele Bammer and Michael Smithson, pp. 289–304. London: Earthscan.

Barber, Bernard. 1983. *The Logic and Limits of Trust*. New Brunswick, NJ: Rutgers University Press.

Barke, Richard P, Hank Jenkins-Smith, and Paul Slovic. 1997. "Risk Perceptions of Men and Women Scientists." *Social Science Quarterly* 78:167–176.

Baron, Jonathan. 1997. "Confusion of Relative and Absolute Risk in Valuation." *Journal of Risk and Uncertainty* 14:301–309.

Barrow, John D. 1998. *Impossibility:* The Limits of Science and the Science of Limits. Oxford: Oxford University Press.

Bassett, Gilbert and Hank Jenkins-Smith. 1992. "Modeling the Effects of Uncertainty on Fear of Nuclear Waste: Differences Among Science, Business and Environmental Group Members." In *Paper prepared for presentation at the Annual Meeting of the Association for Policy Analysis and Management, October 28-31, 1992, Denver Colorado.*, Denver, CO.

Bastide, Sophie, Jean-Paul Moatti, Jean-Pierre Pages, and Francis Fagnani. 1989. "Risk Perception and Social Acceptability of Technologies: The French Case." *Risk Analysis* 9:215–223.

Bateman, Ian, Sam Dent, Ellen Peters, Paul Slovic, and Chris starmer. 2007. "The Affect Heuristic and the Attractiveness of Simple Gambles." *Journal of Behavioral Decision Making* 20:365–380.

Bauman, Zygmunt. 2009. "Seeking in Modern Athens an Answer to the Ancient Jerusalem Question." *Theory, Culture & Society* 26:71–91.

Bauman, Zygmund. 2014. "Jerusalem Versus Athens Revisited." In *Ulrich Beck: Pioneer in Cosmopolitan Sociology and Risk Society*, edited by Ulrich Beck, pp. 71–75. Heidelberg: Springer International Publishing.

Baumol, William J and Wallace C Oates. 1979. Economics, Environmental Policy, and the Quality of Life. Englewood Cliffs, NJ: Prentice Hall.

Beck, Ulrich. 1992. *Risk Society: Toward a New Modernity*. London, UK: Sage.

Beck, Ulrich. 1999. *World Risk Society*. Cambridge, MA: Polity Press.

Beck, Ulrich. 2011. "Cosmopolitanism as Imagined Communities of Global Risk." *American Behavioral Scientist* 55:1346–1361.

Beck, Ulrich. 2014. "Incalculable Futures: World Risk Society and Its Social and Political Implications." In *Ulrich Beck: Pioneer in Cosmopolitan Sociology and Risk Society*, edited by Ulrich Beck, pp. 78–89. Heidelberg: Springer International Publishing.

Beck, Ulrich and Edgar Grande. 2010. "Varieties of Second Modernity: the Cosmopolitan Turn in Social and Political Theory and Research." *The British Journal of Sociology* 61:409–443.

Bella, David A. 1987. "Engineering and Erosion of Trust." *Journal of Professional Issues in Engineering* 113:117–129.

Belzer, R B. 2001. "Getting Beyond 'Grin and Bear It' in the Practice of Risk Management." *Risk Perception Versus Risk Analysis* 72:137–148.

Besley, John C and Sang-Hwa Oh. 2014. "The Impact of Accident Attention, Ideology, and Environmentalism on American Attitudes Toward Nuclear Energy." *Risk Analysis* 34:949–964.

Bickerstaff, Karen, Irene Lorenzoni, Nick F Pidgeon, Wouter Poortinga, and Peter Simmons. 2008. "Reframing Nuclear Power in the UK Energy Debate: Nuclear Power, Climate Change Mitigation and Radioactive Waste." *Public Understanding of Science* 17:145–169.

Biel, Anders and Ulf Dahlstrand. 1995. "Risk perception and the location of a repository for spent nuclear fuel." *Scandinavian Journal of Psychology* 36:25–36.

Biergert, Claus and Elke Stolhofer (eds.). 1993. *Der Tod, der aus der Erde kommt: Zeugnisse nulearer Zerstörung – Ureinwohner der Erde beim World Uranium Hearing*. Salzburg, Austria: Verlag Anton Pustet.

Blocker, T Jean and Douglas Lee Eckberg. 1989. "Environmental Issues as Women's Issues: General Concerns and Local Hazards." *Social Science Quarterly (University of Texas Press)* 70:586–593.

Boghossian, Paul. 2006. *Fear of Knowledge: Against Relativism and Constructivism*. New York: Oxford University Press.

Boholm, Asa. 1998. "Comparative studies of risk perception: a review of twenty years of research." *Journal of Risk Research* 1:135–163.

Bord, Richard J and Robert E O'Connor. 1992. "Determinants of Risk Perceptions of a Hazardous Waste Site." *Risk Analysis* 12:411–416.

Bouyer, Muriel, Sophie Bagdassarian, Sveti Chaabanne, and Etienne Mullet. 2001. "Personality Correlates of Risk Perception." *Risk Analysis* 21:457–466.

Braga, João N, Mário B Ferreira, and Steven J Sherman. 2015. "The effects of construal level on heuristic reasoning: The case of representativeness and availability." *Decision* 2:216–227.

Brandon, Ruth. 1987. *The Burning Question: The anti-nuclear movement since 1945*. London: Heinemann.

Breakwell, Glynis Marie. 2007. *The Psychology of Risk*. Cambridge, UK: Cambridge University Press.

Brede, Karola. 1990. "After Chernobyl: the relation of anxiety to technology in West Germany." *Industrial Crisis Quarterly* 4:233–241.

Brenot, Jean, Sylviane Bonnefous, and Claire Marris. 1998. "Testing the Cultural Theory of Risk in France." *Risk Analysis* 18:729–739.

Brody, Charles J. 1984. "Differences by Sex in Support for Nuclear Power." *Social Forces* 63:209–228.

Brouard, Sylvain and Isabelle Guinaudeau. 2014. "Policy beyond politics? Public opinion, party politics and the French pro-nuclear energy policy." *Journal of Public Policy* 35:137–170.

Byrne, John and Steven M Hoffman. 1988. "Nuclear Power and Technological Authoritarianism." *Bulletin of Science, Technology & Society* 7:658–671.

Byrne, John and Steven M Hoffman. 1996. "Introduction." In *Governing the Atom: The Politics of Risk*, edited by John Byrne and Steven M Hoffman, pp. 1–10. New Brunswick, NJ: Transaction Publishers.

Camerer, Colin and Martin Weber. 1992. "Recent Developments in Modeling Preferences: Uncertainty and Ambiguity." *Journal of Risk and Uncertainty* 5:325–370.

Campbell, Scott and Greg Currie. 2006. "Against Beck: In Defence of Risk Analysis." *Philosophy of the Social Sciences* 36:149–172.

Carmichael, Jason T, J Craig Jenkins, and Robert J Brulle. 2012. "Building Environmentalism: The Founding of Environmental Movement Organizations in the United States, 1900–2000." *Sociological Quarterly* 53:422–453.

Carstensen, Laura L, Derek M Isaacowitz, and Susan T Charles. 1999. "Taking time seriously: A theory of socioemotional selectivity." *American Psychologist* 54:165–181.

Cebulla, Andreas. 2009. "Risk through the years – a statistical portrait of young people's risk perceptions and experiences relative to those of older generations." *Journal of Youth Studies* 12:39–56.

Chodorow, Nancy. 1978. *The reproduction of mothering : psychoanalysis and the sociology of gender*. Berkeley, CA: University of California Press.

Coleman, James Samuel. 1990. *Foundations of Social Theory*. Cambridnge (MA): Harvard University Press, 1 edition.

Conchie, Stacey M, Ian J Donald, and Paul J Taylor. 2006. "Trust: Missing Piece(s) in the Safety Puzzle." *Risk Analysis* 26:1097–1104.

Connell, Robert W. 1990. "A Whole New World: Remaking Masculinity in the Context of the Environmental Movement." *Gender & Society* 4:452–478.

Connell, Robert W. 1993. "The Big Picture: Masculinities in Recent World History." *Theory and Society* 22:597–623.

Connell, Robert W. 1995. *Masculinities*. Cambridge: Polity Press.

Corner, Adam, Dan Venables, Alexa Spence, Wouter Poortinga, Christina Demski, and Nick Pidgeon. 2011. "Nuclear power, climate change and energy security: Exploring British public attitudes." *Energy Policy* 39:4823–4833.

Cornia, Alessio, Kerstin Dressel, and Patricia Pfeil. 2014. "Risk cultures and dominant approaches towards disasters in seven European countries." *Journal of Risk Research* pp. 1–17.

Costa-Font, Joan, Caroline Rudisill, and Elias Mossialos. 2008. "Attitudes as an Expression of Knowledge and "Political Anchoring": The Case of Nuclear Power in the United Kingdom." *Risk Analysis* 28:1273–1288.

Covello, Vincent T. 1983. "The Perception of Technological Risks: a Literature Review." *Technological Forecasting and Social Change* 23:285–297.

Curthoys, Ann. 2008. "Historians and Dispute over Uncertainty." In *Uncertainty and Risk: Multidisciplinary Perspectives*, edited by Gabriele Bammer and Michael Smithson, pp. 127–136. London: Earthscan.

Cvetkovich, George and Timothy C Earle. 1985. "Classifying Hazardous Events." *Journal of Environmental Psychology* 5:5–35.

Cvetkovich, George and Ragnar E Löfstedt. 1999. *Social Trust and the Management of Risk*. London, UK: Earthscan.

Cvetkovich, George, Michael Siegrist, Rachel Murray, and Sarah Tragesser. 2002. "New Information and Social Trust: Asymmetry and Perseverance of Attributions about Hazard Managers." *Risk Analysis* 22:359–367.

Dake, Karl. 1991. "Orienting Dispositions in the Perception of Risk: An Analysis of Contemporary Worldviews and Cultural Biases." *Journal of Cross-Cultural Psychology* 22:61–82.

Dake, Karl. 1992. "Myths of Nature: Culture and the Social Construction of Risk." *Journal of Social Issues* 48:21–37.

Damasio, Antonio. 1994. *Descartes' Error: Emotion, Reason and the Human Brain*. New York: Putnam.

Davidson, Debra J and Willam R Freudenburg. 1996. "Gender and Environmental Risk Concerns: A Review and Analysis of Available Research." *Environment and Behavior* 28:302–339.

De Fazio, Gianluca. 2012. "Legal opportunity structure and social movement strategy in Northern Ireland and southern United States." *International Journal of Comparative Sociology* 53:3–22.

de Finetti, Bruno. 2008. *Philosophical Lectures on Probability*. Collected, Edited, and Annotated by Alberto Mura. Springer Science & Business Media.

De Marchi, Bruna and Jerome R Ravetz. 1999. "Risk management and governance: a post-normal science approach." *Futures* 31:743–757.

Diekmann, Andreas, Reto Meyer, Christa Mühlmann, and Andrea Diem. 2009. *Schweizer Umweltsurvey 2007. Analysen und Ergebnisse. Bericht für das Bundesamt für Statistik (BFS) und das Bundesamt für Umwelt (BAFU).* Zürich: Professur für Soziologie, ETH Zürich.

Diekmann, Andreas and Peter Preisendörfer. 2001. *Umweltsoziologie: Eine Einführung*. Reinbek: Rowohlt.

Dietz, Thomas. 2015. "Environmental Values." In *Oxford Handbook of Values*, edited by T Brosch and D Sander, pp. 329–349. Oxford: Oxford University Press.

Dietz, Thomas and Paul C Stern. 1995. "Toward a Theory of Choice: Socially Embedded Preference Construction." *The Journal of Socio-Economics* 24:261–279.

Dietz, Thomas, Paul C Stern, and Gregory A. Guagnano. 1998. "Social Structural and Social Psychological Bases of Environmental Concern." *Environment and Behavior* 30:450–471.

Dockins, Chris, Robin R Jenkins, Nicole Owens, Nathalie B Simon, and Lanelle Bembenek Wiggins. 2002. "Valuation of Childhood Risk Reduction: The Importance of Age, Risk Preferences, and Perspective." *Risk Analysis* 22:335–346.

Doherty, Brian and Graeme Hayes. 2014. "Having Your Day in Court: Judicial Opportunity and Tactical Choice in Anti-GMO Campaigns in France and the United Kingdom." *Comparative Political Studies* 47:3–29.

Donaldson, Mike. 1993. "What Is Hegemonic Masculinity?" *Theory and Society* 22:643–657.

Douglas, Mary. 1973. *Natural Symbols*. London: Barrie and Jenkins.

Douglas, Mary. 2003. "Being Fair to Hierarchists." *University of Pennsylvania Law Review* 151:1349–1370.

Douglas, Mary and Aaron Wildavsky. 1983. *Risk and Culture: An Essay on the Selection of Technological and Environmental Dangers*. Berkeley, CA: University of California Press.

Drottz-Sjöberg, Britt-Marie and Lennart Sjöberg. 1990. "Risk Perception and Worries After the Chernobyl Accident." *Journal of Environmental Psychology* 10:135–149.

Dryzek, John S, Christian Hunold, David Schlosberg, David Downes, and Hans-Kristian Hernes. 2002. "Environmental Transformation of the State: the USA, Norway, Germany and the UK." *Political Studies* 50:659–682.

Dunlap, Riley E. 1975. "The Impact of Political Orientation on Environmental Attitudes and Actions." *Environment and Behavior* 7:428.

Dunlap, Riley E. and Robert E Jones. 2002. "Environmental Concern: Conceptual and Measurement Issues." In *Handbook of Environmental Sociology*, edited by Riley E. Dunlap, pp. 482–524. Westport, CT: Greenwood Press.

Dunlap, Riley E. and Richard York. 2008. "The Globalization of Environmental Concern and the Limits of the Postmaterialist Values Explanation: Evidence from Four Multinational Surveys." *The Sociological Quarterly* 49:529–563.

Dunwoody, Sharon and Hans Peter Peters. 1992. "Mass media coverage of technological and environmental risks: a survey of research in the United States and Germany." *Public Understanding of Science* 1:199–230.

Earle, Timothy C and George Cvetkovich. 1990. "What Was the Meaning of Chernobyl?" *Journal of Environmental Psychology* 10:169–176.

Edwards, Ward. 1954. "The Theory of Decision Making." *Psychological Bulletin* 51:380–417.

Edwards, Ward and Detlof von Winterfeldt. 1987. "Public Values in Risk Debates." *Risk Analysis* 7:141–158.

Eisenberg, Eric M. 2001. "Building a Mystery: Toward a New Theory of Communication and Identity." *Journal of Communication* 51:534–552.

Eisenhower, Dwight D. 1953. "Atoms for Peace: Address Before the General Assembly of the United Nations on Peaceful Uses of Atomic Energy, New York City, December 8th, 1953." *Eisenhower Archives* .

Eisenhower, Dwight D. 1961. "Presidential Farewell Address." *AmericanRethoric.com* .

Eiser, J Richard, Bettina Hannover, Leon Mann, Michel Morin, Joop van Der Pligt, and Paul Webley. 1990. "Nuclear Attitudes After Chernobyl: a Cross-National Study." *Journal of Environmental Psychology* 10:101–110.

Eiser, J Richard, Russell Spears, and Paul Webley. 1989. "Nuclear Attitudes Before and After Chernobyl: Change and Judgment." *Journal of Applied Social Psychology* 19:689–700.

Eiser, J Richard and Joop van der Pligt. 1982. "Accentuation and Perspective in Attitudinal Judgment." *Journal of Personality and Social Psychology* 42:224–238.

Ekberg, Merryn. 2007. "The Parameters of the Risk Society: A Review and Exploration." *Current Sociology* 55:343–366.

Ellsberg, Daniel. 1961. "Risk, Ambiguity, and the Savage Axioms." *The quarterly journal of economics* 75:643–669.

Ellsberg, Daniel. 2001. *Risk, Ambiguity and Decision*. New York: Routledge.

Epstein, Seymour. 1994. "Integration of the Cognitive and the Psychodynamic Unconscious." *American Psychologist* 49:709–724.

Epstein, Seymour, Abigail Lipson, Carolyn Holstein, and Eileen Huh. 1992. "Irrational Reactions to Negative Outcomes: Evidence for Two Conceptual Systems." *Journal of Personality and Social Psychology* 62:328–339.

Faucheux, Claude. 1976. "Cross-cultural research in experimental social psychology." *European Journal of Social Psychology* 6:269–322.

Feldhoff, Thomas. 2014. "Post-Fukushima energy paths: Japan and Germany compared." *Bulletin of the Atomic Scientists* 70:87–96.

Festinger, Leon. 1957. *A Theory of Cognitive Dissonance*. Evanston, Ill: Row, Peterson.

Fetherstonhaugh, David, Paul Slovic, Stephen M Johnson, Steven Johnson, and James Friedrich. 1997. "Insensitivity to the Value of Human Life: A Study of Psychophysical Numbing." *Journal of Risk and Uncertainty* 14:283–300.

Feyerabend, Paul. 1970. "Wie wird man ein braver Empirist? Ein Aufruf zur Toleranz in der Erkenntnistheorie." In *Erkenntnisprobleme der Naturwissenschaften*, edited by Lorenz Krüger, pp. 302–335. Cologne, Germany: Kiepenheuer und Witsch.

Feyerabend, Paul. 1984. *Wissenschaft als Kunst*. Suhrkamp.

Feyerabend, Paul. 1993. *Against Method*. London: Verso Books, 3 edition.

Feygina, Irina, John T Jost, and Rachel E Goldsmith. 2010. "System Justification, the Denial of Global Warming, and the Possibility of "System-Sanctioned Change"." *Personality and Social Psychology Bulletin* 36:326–338.

Field, Barry C and Marta K Field. 2009. Environmental Economics: An Introduction. Boston: McGraw-Hill, 6 edition.

Figueroa, Pablo M. 2013. "Risk communication surrounding the Fukushima nuclear disaster: an anthropological approach." *Asia Europe Journal* 11:53–64–64.

Finucane, Melissa L, Ali Alhakami, Paul Slovic, and Stephen M Johnson. 2000a. "The Affect Heuristic in Judgments of Risks and Benefits." Journal of Behavioral Decision Making.

Finucane, Melissa L, Ellen Peters, and Paul Slovic. 2003. "Judgment and decision making: The dance of affect and reason." In *Emerging Perspectives on Judgment and Decision Research*, edited by Sandra L Schneider and James Shanteau, pp. 327–364. Cambridge, UK: Cambridge University Press.

Finucane, Melissa L, Paul Slovic, C K Mertz, James Flynn, and Theresa A Satterfield. 2000b. "Gender, race, and perceived risk: the 'white male' effect." *Health, Risk & Society* 2:159–172.

Fiorino, Daniel J. 1989. "Technical and Democratic Values in Risk Analysis." *Risk Analysis* 9:293–299.

Fischhoff, Baruch. 1995. "Risk Perception and Communication Unplugged: Twenty Years of Process." *Risk Analysis* 15:137–145.

Fischhoff, Baruch, Paul Slovic, Sarah Lichtenstein, Stephen Read, and Barbara Combs. 1978. "How Safe Is Safe Enough? a Psychometric Study of Attitudes Towards Technological Risks and Benefits." *Policy Sciences* 9:127–152.

Flynn, James, William Burns, C K Mertz, and Paul Slovic. 1992. "Trust as a Determinant of Opposition to a High-Level Radioactive Waste Repository: Analysis of a Structural Model." *Risk Analysis* 12:417–429.

Flynn, James, Ellen Peters, C K Mertz, and Paul Slovic. 1998. "Risk, Media, and Stigma at Rocky Flats." *Risk Analysis* 18:715–725.

Flynn, James, Paul Slovic, and C K Mertz. 1993. "The Nevada Initiative: A Risk Communication Fiasco." *Risk Analysis* 13:497–502.

Flynn, James, Paul Slovic, and C K Mertz. 1994. "Gender, Race, and Perception of Environmental Health Risks." *Risk Analysis* 14:1101–1108.

Forbes, Linda C and Laura Sells. 1997. "Reorganizing the Woman/Nature Connection." *Organization & Environment* 10:20–22.

Fowlkes, M A and P Y Miller. 1987. "Chemicals and community at Love Canal." In *The Social and Cultural Construction of Risk: Essays on Risk Selection and Perception*, edited by Branden B Johnson and Vincent T Covello, pp. 55–78. Dordrecht, the Netherlands: Reidel.

Fox, Mary Frank and Glenn Firebaugh. 1992. "Confidence in Science: The Gender Gap." *Social Science Quarterly* 73:101–113.

Frankena, William K. 2006. "Values and valuation." In *Encyclopedia of Philosophy*, edited by Donald M Borchert, pp. 636–641. Detroit, MI: Macmillan Reference USA.

Fransson, Niklas and Tommy Gärling. 1999. "Environmental Concern: Conceptual Definitions, Measurement Methods, and Research Findings." *Journal of Environmental Psychology* 19:369–382.

Franzen, Axel and Reto Meyer. 2010. "Environmental Attitudes in Cross-National Perspective: A Multilevel Analysis of the ISSP 1993 and 2000." *European Sociological Review* 26:219–234.

Franzen, Axel and Dominikus Vogl. 2011. "Pitfalls of International Comparative Research: Taking Acquiescence into Account." *Journal of Economics and Statistics (Jahrbuecher fuer Nationaloekonomie und Statistik)* 231:761–782.

Franzen, Axel and Dominikus Vogl. 2013a. "Acquiescence and the Willingness to Pay for Environmental Protection: A Comparison of the ISSP, WVS, and EVS." *Social Science Quarterly* 94:637–659.

Franzen, Axel and Dominikus Vogl. 2013b. "Time Preferences and Environmental Concern." *International Journal of Sociology* 43:39–62.

Franzen, Axel and Dominikus Vogl. 2013c. "Two decades of measuring environmental attitudes: A comparative analysis of 33 countries." *Global Environmental Change* 23:1001–1008.

Frederick, Shane, George F Loewenstein, and Ted O'Donogue. 2002. "Time Discounting and Time Preference: A Critical Review." *Journal of Economic Literature* 40:351–401.

Freudenburg, William R. 1988. "Perceived Risk, Real Risk: Social Science and the Art of Probabilistic Risk Assessment." *Science* 242:44–49.

Freudenburg, William R. 1991. "Rural-Urban Differences in Environmental Concern: A Closer Look." *Sociological Inquiry* 61:167–198.

Freudenburg, William R. 1992. "Nothing Recedes Like Success - Risk Analysis and the Organizational Amplification of Risks." *Risk: Issues in Health and Safety* 3:1–35.

Freudenburg, William R. 1993. "Risk and Recreancy: Weber, the Division of Labor, and the Rationality of Risk Perceptions." *Social Forces* 71:909–932.

Freudenburg, William R, Cynthia-Lou Coleman, James Gonzales, and Catherine Helgeland. 1996. "Media Coverage of Hazard Events: Analyzing the Assumptions." *Risk Analysis* 16:31–42.

Freudenburg, William R and Timothy R Jones. 1991. "Attitudes and Stress in the Presence of Technological Risk: A Test of the Supreme Court Hypothesis." *Social Forces* 69:1143–1168.

Freudenburg, William R and Susan K Pastor. 1992. "Public Responses to Technological Risks: Toward a Sociological Perspective." *Sociological Quarterly* 33:389–412.

Frewer, Lynn J, Susan Miles, Mary Brennan, Sharon Kuznesof, Mitchell Ness, and Christopher Ritson. 2002. "Public preferences for informed choice under conditions of risk uncertainty." *Public Understanding of Science* 11:363–372.

Fukuyama, Francis. 1995. *Trust: The Social Virtues and the Creation of Prosperity*. New York, NY: The Free Press.

Gasper, Karen and Gerald L Clore. 1998. "The Persistent Use of Negative Affect by Anxious Individuals to Estimate Risk." *Journal of Personality and Social Psychology* 74:1350–1363.

Gattig, Alexander and Laurie Hendrickx. 2007. "Judgmental Discounting and Environmental Risk Perception: Dimensional Similarities, Domain Differences, and Implications for Sustainability." *Journal of Social Issues* 63:21–39.

Gelissen, John. 2007. "Explaining Popular Support for Environmental Protection: A Multilevel Analysis of 50 Nations." *Environment and Behavior* 39:392–415.

George, David L and Priscilla L Southwell. 1986. "Opinion on the Diablo Canyon Nuclear Power Plant: the Effects of Situation and Socialization." *Social Science Quarterly* 67:722–735.

Giddens, Anthony. 1990. *The Consequences of Modernity*. Stanford, California: Stanford University Press.

Giddens, Anthony. 1994. *Beyond Left and Right: The Future of Radical Politics*. Stanford, CA: Stanford University Press.

Giddens, Anthony. 2002. *Runaway world : how globalisation is reshaping our lives*. London: Profile Books, 2 edition.

Gigerenzer, Gerd. 1991. "How to Make Cognitive Illusions Disappear: Beyond "Heuristics and Biases"." *European Review of Social Psychology* 2:83–115.

Gigerenzer, Gerd. 1996. "Why do frequency formats improve Bayesian reasoning? Cognitive algorithms work on information, which needs representation." *Behavioral and Brain Sciences* 19:23–24.

Gigerenzer, Gerd. 2003. *Reconing with Risk: Learning to live with uncertainty*. London: Penguin Books.

Gigerenzer, Gerd. 2008a. *Rationality for mortals: how people cope with uncertainty*. Oxford: Oxford University Press.

Gigerenzer, Gerd. 2008b. "Why Heuristics Work." *Perspectives on Psychological Science* 3:20–29.

Gill, Jeff. 2008. *Bayesian Methods: A Social and Behavioral Sciences Approach*. London: Chapman & Hall/CRC.

Goebel, Jan, Christian Krekel, Tim Tiefenbach, and Nicolas R Ziebarth. 2015. "How natural disasters can affect environmental concerns, risk aversion, and even politics: evidence from Fukushima and three European countries." *Journal of Population Economics* 28:1137–1180.

Goszczynska, Maryla, Tadeusz Tyszka, and Paul Slovic. 1991. "Risk Perception in Poland: a Comparison with Three Other Countries." *Journal of Behavioral Decision Making* 4:179–193.

Greenberg, Michael. 2009. "Energy sources, public policy, and public preferences: Analysis of US national and site-specific data." 37:3242–3249.

Greenberg, Michael and Heather Barnes Truelove. 2011. "Energy Choices and Risk Beliefs: Is It Just Global Warming and Fear of a Nuclear Power Plant Accident?" *Risk Analysis* 31:819–831.

Greenberg, Michael R and Dona F Schneider. 1995. "Gender Differences in Risk Perception: Effect Differ in Stress vs. Non-Stressed Environments." *Risk Analysis* 15:503–511.

Greenwald, Anthony G. 1980. "The Totalitarian Ego: Fabrication and Revision of Personal History." *American Psychologist* 35:603–618.

Gregory, Robin S, James Flynn, and Paul Slovic. 1995. "Technological stigma." *American Scientist* 83:220–223.

Gregory, Robin S and Theresa A Satterfield. 2002. "Beyond Perception: The Experience of Risk and Stigma in Community Contexts." *Risk Analysis* 22:347–358.

Grendstad, Gunnar. 2000. "Grid-Group Theory and Political Orientations: Effects of Cultural Biases in Norway in the 1990s." *Scandinavian Political Studies* 23:217–244.

Grendstad, Gunnar and Per Selle. 2000. "Cultural Myths of Human and Physical Nature: Integrated or Separated?" *Risk Analysis* 20:27–40.

Gudykunst, William B and Tsukasa Nishida. 2001. "Anxiety, uncertainty, and perceived effectiveness of communication across relationships and cultures." *International Journal of Intercultural Relations* 25:55–71.

Habermas, Jürgen. 1971. *Toward a rational society*. London: Heinemann.

Hamilton, Lawrence C. 1985. "Concern about Toxic Wastes: Three Demographic Predictors." *Sociological Perspectives* 28:463–486.

Hamilton, Lawrence C, Joel Hartter, Thomas G Safford, and Forrest R Stevens. 2013. "Rural Environmental Concern: Effects of Position, Partisanship, and Place." *Rural Sociology* 79:257–281.

Hartmann, Patrick, Vanessa Apaolaza, Clare D'Souza, Carmen Echebarria, and Jose M Barrutia. 2013. "Nuclear power threats, public opposition and green electricity adoption: Effects of threat belief appraisal and fear arousal." *Energy Policy* 62 IS -:1366–1376.

Hatch, Michael T. 1996. "Nuclear Power and Postindustrial Politics in the West." In *Governing the Atom: The Politics of Risk*, edited by John Byrne and Steven M Hoffman, pp. 201–246. New Brunswick, NJ: Transaction Publishers.

Hayles, N Katherine. 1995. "Searching for Common Ground." In *Reinventing Nature? Responses to Postmodern Deconstruction*, edited by Michael Soulé and Gary Lease, pp. 47–63. Washington, D.C.: Island Press.

Heath, Yuko and Robert Gifford. 2006. "Free-Market Ideology and Environmental Degradation the Case of Belief in Global Climate Change." *Environment and Behavior* 38:48–71.

Hecht, Gabrielle. 1998. *The Radiance of France: Nuclear Power and National Identity after World War II*. Cambridge, MA: The MIT Press.

Hendrickx, Laurie, Charles Vlek, and Harmen Oppewal. 1989. "Relative Importance of Scenario Information and Frequency Information in the Judgment of Risk." *Acta Psychologica* 72:41–63.

Henry, Adam Douglas. 2009. "The Challenge of Learning for Sustainability: A Prolegomenon to Theory." *Human Ecology Review* 16:131–140.

Hill, C N. 2013. *An Atomic Empire: A Technical History of the Rise and Fall of the British Atomic Energy Programme*. London: Imperial College Press.

Hinman, George W, Eugene A Rosa, Randall R Kleinhesselink, and Thomas C Lowinger. 1993. "Perceptions of Nuclear and Other Risks in Japan and the United States." *Risk Analysis* 13:449–455.

Hogarth, Robin M. 1980. *Judgement and Choice: The Psychology of Decsion*. London: Wiley.

Horlick-Jones, Tom, Gene Rowe, and John Walls. 2007. "Citizen engagement processes as information systems: the role of knowledge and the concept of translation quality." *Public Understanding of Science* 16:259–278.

Hornig, Susanna. 1992. "Gender Differences in Responses to News about Science and Technology." *Science, Technology, & Human Values* 17:532–542.

Hoy, Andrew R. 1994. "The Relationship Between Male Dominance and Militarism: Quantitative Tests of Several Theories." *World Cultures* 8:40–57.

IAEA International Atomic Energy Agency. 2015. "PRIS: Power Reactor Information System."

Inglehart, Ronald. 1988. "The Renaissance of Political Culture." *The American Political Science Review* 82:1203–1230.

Inglehart, Ronald. 1990. Culture shift in advanced industrial society. Princeton, NJ: Princeton University Press.

Inglehart, Ronald. 1995. "Public Support for the Environmental Protection: Objective Problems and Subjective Values in 43 Societies." *Political Science and Politics* 28:57–72.

Inglehart, Ronald. 1997. *Modernization and Postmodernization: Cultural, Economic, and Political Change in 43 Societies*. Princeton, NJ: Princeton University Press.

ISSP. 2012. "*International Social Survey Programme 2010: Environment III (ISSP 2010)*." GESIS Data Archive.

Izard, Carroll E. 1991. *The Psychology of Emotions*. New York: Plenum Press.

Jaeger, Carlo C, Thomas Webler, Eugene A Rosa, and Ortwin Renn. 2001. *Risk, Uncertainty and Rational Action*. London: Earthscan.

Jann, Ben. 2007. "Making regression tables simplified." *Stata Journal* 7:227–244.

Jann, Ben. 2014. "Plotting regression coefficients and other estimates." *Stata Journal* 14:708–737.

Jann, Ben and J Scott Long. 2010. "Tabulating SPost results using estout and esttab." *Stata Journal* 10:46–60.

Jasanoff, Sheila. 1989. "Norms for Evaluating Regulatory Science." *Risk Analysis* 9:271–273.

Jasanoff, Sheila. 1993. "Bridging the Two Cultures of Risk Analysis." *Risk Analysis* 13:123–129.

Jasanoff, Sheila. 1996. "Beyond Epistemology: Relativism and Engagement in the Politics of Science." *Social Studies of Science* 26:393–418.

Jasanoff, Sheila. 1999. "The Songlines of Risk ." *Environmental Values* 9:135–152.

Jasanoff, Sheila. 2006. “Risk in Hindsight - Towards a Politics of Reflection .” In *Risk Society and the Culture of Precaution*, edited by Ingo K Richter, Sabine Berking, and Ralf Müller-Schmid, pp. 28–46. New York: Palgrave Mamillan.

Jasper, James M. 1996. “Nuclear Policy as Projection: How Policy Choices Can Create Their Own Justification.” In *Governing the Atom: The Politics of Risk*, edited by John Byrne and Steven M Hoffman, pp. 47–66. New Brunswick, NJ: Transaction Publishers.

Jenkins, J Craig, Michael Wallace, and Andrew S Fullerton. 2008. “A Social Movement Society? A Cross-National Analysis of Protest Potential.” *International Journal of Sociology* 38:12–35.

Jenkins-Smith, Hank C. 1991. “Alternative Theories of the Policy Process: Reflections on Research Strategy for the Study of Nuclear Waste Policy.” *PS: Political Science and Politics* 24:157–166.

Johnson, Branden B. 1987. “The environmentalist movement and grid/group analysis: A modest critique.” In *The Social and Cultural Construction of Risk: Essays on Risk Selection and Perception*, edited by Branden B Johnson and Vincent T Covello, pp. 147–178. Dordrecht, the Netherlands: Reidel.

Johnson, Branden B. 1991. “Risk and Culture Research: Some Cautions.” *Journal of Cross-Cultural Psychology* 22:141–149.

Joppke, Christian. 1993. *Mobilizing Against Nuclear Energy: A Comparision of Germany and the United States*. Berkeley, CA: University of California Press.

Jost, John T, Brian A Nosek, and Samuel D Gosling. 2008. “Ideology: Its Resurgence in Social, Personality, and Political Psychology.” *Perspectives on Psychological Science* 3:126–136.

Jungermann, Helmut, Hans-Rüdiger Pfister, and Katrin Fischer. 1996. “Credibility, Information Preferences, and Information Interests.” *Risk Analysis* 16:251–261.

Kahan, Dan M, Donald Braman, John Gastil, Paul Slovic, and C K Mertz. 2007. “Culture and Identity-Protective Cognition: Explaining the White-Male Effect in Risk Perception.” *Journal of Empirical Legal Studies* 4:465–505.

Kahneman, Daniel. 1994. “New Challenges to the Rationality Assumption.” *Journal of Institutional and Theoretical Economics (JITE) / Zeitschrift für die gesamte Staatswissenschaft* 150:18–36.

Kahneman, Daniel. 2003. “A Perspective on Judgment and Choice: Mapping Bounded Rationality.” *American Psychologist* 58:697–720.

Kahneman, Daniel and Jackie Snell. 1992. “Predicting a Changing Taste: Do People Know What They Will Like?” *Journal of Behavioral Decision Making* 5:187–200.

Kahneman, Daniel and Amos Tversky. 1972. "Subjective Probability: a Judgment of Representativeness." *Cognitive Psychology* 3:430–454.

Kahneman, Daniel and Amos Tversky. 1979. "Prospect Theory: An Analysis of Decision under Risk." *Econometrica* 47:263–291.

Kahneman, Daniel and Amos Tversky. 1984. "Choices, Values, and Frames." *American Psychologist* 39:341–350.

Karpowicz-Lazreg, C and E Mullet. 1993. "Societal Risk as Seen by the French Public." *Risk Analysis* 13:253–258.

Kasperson, Jeanne X, Roger E Kasperson, Nick F Pidgeon, and Paul Slovic. 2003. "The social amplification of risk: Assessing fifteen years of research and theory." In *The Social Amplification of Risk*, edited by Nick F Pidgeon, Roger E Kasperson, and Paul Slovic, pp. 13–46. Cambridge UK: Cambridge University Press.

Kasperson, Roger. 2014. "Four questions for risk communication." *Journal of Risk Research* 17:1233–1239.

Kasperson, Roger E. 2013. "Opportunities and Dilemmas in Managing Risk and Uncertainty." In *Structural Human Ecology: New Essays in Risk, Energy, and Sustainability*, edited by Thomas Dietz and Andrew K Jorgenson, pp. 73–89. Pullman, Washington: Washington State University Press.

Kasperson, Roger E, Dominic Golding, and Seth Tuler. 1992. "Social Distrust as a Factor in Siting Hazardous Facilities and Communicating Risks." *Journal of Social Issues* 48:161–187.

Kasperson, Roger E, Ortwin Renn, Paul Slovic, Halina S Brown, Jacque Emel, Robert Goble, Jeanne X Kasperson, and Samuel Ratick. 1988. "The Social Amplification of Risk: A Conceptual Framework." *Risk Analysis* 8:177–187.

Keller, Carmen, Vivianne Visschers, and Michael Siegrist. 2011. "Affective Imagery and Acceptance of Replacing Nuclear Power Plants." *Risk Analysis* 32:464–477.

Keynes, John M. 1921. *A Treaties on Probability*. New York: Harper and Row.

Kim, Younghwan, Minki Kim, and Wonjoon Kim. 2013. "Effect of the Fukushima nuclear disaster on global public acceptance of nuclear energy." *Energy Policy* 61:822–828.

Kingston, Jeff. 2014. "Japan's nuclear village: power and resilience." In *Critical Issues in Contemporary Japan*, edited by Jeff Kingston, pp. 107–119. New York: Routledge.

Kitschelt, Herbert P. 1986. "Political Opportunity Structures and Political Protest: Anti-Nuclear Movements in Four Democracies." *British Journal of Political Science* 16:57–85.

Klein, Gary. 1997. "Developing Expertise in Decision Making." *Thinking & Reasoning* 3:337–352.

Klein, Naomi. 2007. *The Shock Doctrine: The Rise of Disaster Capitalism*. New York: Metropoitan Books.

Kleinhesselink, Randall R and Eugene A Rosa. 1991. "Cognitive Representation of Risk Perceptions: A Comparison of Japan and the United States." *Journal of Cross-Cultural Psychology* 22:11–28.

Klinke, Andreas and Ortwin Renn. 2002. "A New Approach to Risk Evaluation and Management: Risk-Based, Precaution-Based, and Discourse-Based Strategies." *Risk Analysis* 22:1071–1094.

Klinke, Andreas and Ortwin Renn. 2012. "Adaptive and integrative governance on risk and uncertainty." *Journal of Risk Research* 15:273–292.

Knight, Andrew J and Rex Warland. 2005. "Determinants of Food Safety Risks: A Multi-disciplinary Approach." *Rural Sociology* 70:253–275.

Knight, Frank H. 1921. *Risk, Uncertainty and Profit*. Boston: Houghton Mifflin.

Koopmans, Ruud and Jan Willem Duyvendak. 1995. "The Political Construction of the Nuclear Energy Issue and Its Impact on the Mobilization of Anti-Nuclear Movements in Western Europe." *Social Problems* 42:235–251.

Kuhn, Thomas. 1970. *The Structure of Scientific Revolution*. Chicago: University of Chicago Press, 2 edition.

Kuklinski, James H, Daniel S Metlay, and W D Kay. 1982. "Citizen Knowledge and Choices on the Complex Issue of Nuclear Energy." *American Journal of Political Science* 26:615–642.

Kunreuther, Howard, Douglas Easterling, William Desvousges, and Paul Slovic. 1990. "Public Attitudes Toward Siting a High-Level Nuclear Waste Repository in Nevada." *Risk Analysis* 10:469–484.

Kurlansky, Mark J. 1981. "Separatists and Nuclear Power." *Environment* 23:2–5.

Lakatos, Imre and Paul Feyerabend. 1999. *For and Against Method: Including Lakatos's lectures on scientific method and Lakatos-Feyerabend correspondence*. Chicago: The University of Chicago Press.

Langford, Ian H, Stavros Georgiou, Ian J Bateman, Rosemary J Day, and R Kerry Turner. 2000. "Public Perceptions of Health Risks from Polluted Coastal Bathing Waters: A Mixed Methodological Analysis Using Cultural Theory." *Risk Analysis* 20:691–704.

Latour, Bruno. 1987. *Science in Action*. Milton Keynes: Open University Press.

Lee, Terence R. 1986. "Effective Communication of Information About Chemical Hazards." *Science of The Total Environment* 51:149–183.

Levine, Adeline G. 1982. *Love canal: Science, politics, and people*. Lexington, MA: Lexington Books.

Lichtenstein, Sarah, Paul Slovic, Baruch Fischhoff, Mark Layman, and Barbara Combs. 1978. "Judged frequency of lethal events." *Journal of Experimental Psychology: Human Learning and Memory* 4:551–578.

Liebe, Ulf, Peter Preisendörfer, and Jürgen Meyerhoff. 2011. "To Pay or Not to Pay: Competing Theories to Explain Individuals' Willingness to Pay for Public Environmental Goods." *Environment and Behavior* 43:106–130.

Lindell, Michael K and Ronald W Perry. 1990. "Effects of the Chernobyl Accident on Public Perceptions of Nuclear Plant Accident Risks." *Risk Analysis* 10:393–399.

Linnerooth-Bayer, Joanne and Kevin B Fitzgerald. 1996. "Conflicting Views on Fair Siting Processes: Evidence from Austria and the U.S." *Risk Issues in Health, Safety and Environment* 7:119–134.

Loewenstein, George F, Elke U Weber, Christopher K Hsee, and Ned Welch. 2001. "Risk as Feelings." *Psychological Bulletin* 127:267–286.

Löfstedt, Ragnar E. 2003. "Risk communication: pitfalls and promises." *European Review* 11:417–435.

Löfstedt, Ragnar E. 2005. *Risk Management in Post-Trust Societies*. New York, NY: Palgrave MacMillan.

Lopes, Lola L. 1991. "The Rhetoric of Irrationality." *Theory & Psychology* 1:65–82.

Luce, R Duncan and Elke U Weber. 1986. "An Axiomatic Theory of Conjoint, Expected Risk." *Journal of Mathematical Psychology* 30:188–205.

Luhmann, Niklas. 1980. *Trust and Power*. New York, NY: Wiley.

Luhmann, Niklas. 1986. *Ökologische Kommunikation*. Opladen: Westdeutsche Verlag.

Luhmann, Niklas. 1990. "Technology, environment and social risk: a systems perspective." *Industrial Crisis Quarterly* 4:223–231.

Luhmann, Niklas. 1995. *Social Systems*. Stanford, CA: Stanford University Press.

Lynn, Frances M. 1986. "The Interplay of Science and Values in Assessing and Regulating Environmental Risks." *Science, Technology, & Human Values* 11:40–50.

MacGregor, Sherilyn. 2010. "A stranger silence still: the need for feminist social research on climate change." *Sociological Review Monograph* 57:124–140.

Machina, Mark J. 1987. "Choice Under Uncertainty: Problems Solved and Unsolved." *The Journal of Economic Perspectives* 1:121–154.

Malkis, Allan and Harold G Grasmick. 1977. "Support for the ideology of the environmental movement: Tests of alternative hypotheses." *Western Sociological Review* 8:25–47.

Maloney, Michael P and Michael P Ward. 1973. "*An Objective Scale for the Measurement of Ecological Attitudes and Knowledge*." *American Psychologist* 28:583–586.

Maloney, Michael P, Michael P Ward, and G Nicholas Braucht. 1975. "A Revised Scale for the Measurement of Ecological Attitudes and Knowledge." *American Psychologist* 30:787–790.

Mandler, George. 1984. *Mind and Body*. Psychology of Emotion and Stress. New York: W. W. Norton.

Mannheim, Karl. 1972. "The problems of generations." In *Karl Mannheim: Essays*, edited by Paul Kecskemeti, pp. 276–322. Routledge.

Marquart-Pyatt, Sandra T. 2008. "Are There Similar Sources of Environmental Concern? Comparing Industrialized Countries." *Social Science Quarterly* 89:1312–1335.

Marquart-Pyatt, Sandra T. 2012. "Contextual influences on environmental concerns cross-nationally: A multilevel investigation." *Social Science Research* 41:1085–1099.

Marris, Claire, Ian H Langford, and Timothy O'Riordan. 1998. "A Quantitative Test of the Cultural Theory of Risk Perceptions: Comparison with the Psychometric Paradigm." *Risk Analysis* 18:635–647.

Maslow, Abraham H. 1970. *Motivation and Personality*. New York: Harper and Row, 2 edition.

McCright, Aaron M and Riley E. Dunlap. 2010. "Anti-reflexivity: The American Conservative Movement's Success in Undermining Climate Science and Policy." *Theory, Culture & Society* 27:100–133.

McCright, Aaron M and Riley E. Dunlap. 2011. "Cool dudes: The denial of climate change among conservative white males in the United States." *Global Environmental Change* 21:1163–1172.

Meyer, Reto and Ulf Liebe. 2010. "Are the affluent prepared to pay for the planet? Explaining willingness to pay for public and quasi-private environmental goods in Switzerland." *Population and Environment* 32:42–65.

Midden, Cees J H and Bas Verplanken. 1990. “The Stability of Nuclear Attitudes After Chernobyl.” *Journal of Environmental Psychology* 10:111–119.

Mohai, Paul. 1992. “Men, women, and the environment: An examination of the gender gap in environmental concern and activism.” *Society and Natural Resources* 5:1–19.

Morioka, Rika. 2014. “Gender difference in the health risk perception of radiation from Fukushima in Japan: The role of hegemonic masculinity.” *Social Science & Medicine* 107:105–112.

Morris, Michael G and Viswanath Venkatesh. 2000. “Age Differences in Technology Adoption Decisions: Implications for a Changing Work Force.” *Personnel Psychology* 53:375–403.

Nakata, Toshihiko. 2011. “Nuclear Energy Development in Japan.” In *Nuclear Energy Development in Asia: Problems and Prospects*, edited by Xu Yi-chong, pp. 98–115. New York: Palgrave MacMillan.

Nakayachi, Kazuya. 2015. “Examining Public Trust in Risk-Managing Organizations After a Major Disaster.” *Risk Analysis* 35:57–67.

Nawrotzki, Raphael J. 2012. “The Politics of Environmental Concern: A Cross-National Analysis.” *Organization & Environment* 25:286–307.

Nelkin, Dorothy. 1981. “Nuclear Power as a Feminist Issue.” *Environment* 23:14–20.

Neumayer, Eric. 2004. “The environment, left-wing political orientation and ecological economics.” *Ecolocical Economist* 51:167–175.

Nisbett, Richard and Lee Ross. 1980. *Human inference : Strategies and shortcomings of social judgment*. Englewood Cliffs, N.J.: Prentice Hall.

Nisbett, Richard E, Kaiping Peng, Incheol Choi, and Ara Norenzayan. 2001. “Culture and Systems of Thought: Holistic Versus Analytic Cognition.” *Psychological Review* 108:291–310.

NOAD. 2005. *New Oxford American Dictionary*. Oxford University Press, 2 edition.

Ogawa, Akihiro. 2014. “Civil Society: past, present, and future.” In *Critical Issues in Contemporary Japan*, edited by Jeff Kingston, pp. 52–63. New York: Routledge.

Olofsson, Anna and Susanna Öhman. 2006. “General Beliefs and Environmental Concern: Transatlantic Comparisons.” *Environment and Behavior* 38:768–790.

Olofsson, Anna and Susanna Öhman. 2014. “Vulnerability, values and heterogeneity: one step further to understand risk perception and behaviour.” *Journal of Risk Research* 18:2–20.

Olofsson, Anna and Saman Rashid. 2011. "The White (Male) Effect and Risk Perception: Can Equality Make a Difference?" *Risk Analysis* 31:1016–1032.

Olofsson, Anna, Jens O Zinn, Gabriele Griffin, Katarina Giritli Nygren, Andreas Cebulla, and Kelly Hannah-Moffat. 2014. "The mutual constitution of risk and inequalities: intersectional risk theory." *Health, Risk & Society* 16:417–430.

Oltedal, Sigve, Bjørg-Elin Moen, Hroar Klempe, and Torbjørn Rundmo. 2004. *Explaining risk perception. An evaluation of cultural theory*. Trondheim: Rotunde no. 85. Norwegian University of Science and Technology, Department of Psychology, Norway.

Pampel, Fred C. 2011. "Support for Nuclear Energy in the Context of Climate Change: Evidence From the European Union." *Organization & Environment* 24:249–268.

Papadakis, Elim. 1984. *The Green Movement in West Germany*. London: Croom Helm.

Parkhill, Karen A, Nick F Pidgeon, Karen L Henwood, Peter Simmons, and Dan Venables. 2010. "From the familiar to the extraordinary: local residents' perceptions of risk when living with nuclear power in the UK." *Transactions of the Institute of British Geographers* 35:39–58.

Parsons, Talcott. 1960. "Pattern Variables Revisited: A Response to Robert Dubin." *American Sociological Review* 25:467–483.

Perrow, Charles. 1999. *Normal Accidents. Living with High-Risk Technologies*. Princeton, NJ: Princeton University Press, 2 edition.

Perrow, Charles. 2006. "Culture, Strucutre and Risk." In *Risk Society and the Culture of Precaution*, edited by Ingo K Richter, Sabine Berking, and Ralf Müller-Schmid, pp. 47–58. New York: Palgrave Mamillan.

Perrow, Charles. 2007. *The Next Catastrophe*. Reducing Our Vulerabilities to Natural, Industrial, and Terrorist Disasters. Princetion, NJ: Princeton University Press.

Perrow, Charles. 2011. "Fukushima and the inevitability of accidents." *Bulletin of the Atomic Scientists* 67:44–52.

Perry, Alfred M and Alvin M Weinberg. 2001. "Nuclear Power and the Greenhouse Effect." *Proceedings of the American Philosophical Society* 145:184–186.

Peters, Ellen and Paul Slovic. 1996. "The Role of Affect and Worldviews as Orienting Dispositions in the Perception and Acceptance of Nuclear Power." *Journal of Applied Social Psychology* 26:1427–1453.

Peters, Ellen M, Burt Burraston, and C K Mertz. 2004. "An Emotion-Based Model of Risk Perception and Stigma Susceptibility: Cognitive Appraisals of Emotion, Affective Reactivity, Worldviews, and Risk Perceptions in the Generation of Technological Stigma†." *Risk Analysis* 24:1349–1367.

Peters, Hans Peter, Gabriele Albrecht, Leo Hennen, and Hans Ulrich Stegelmann. 1990. "'Chernobyl' and the Nuclear Power Issue in West German Public Opinion." *Journal of Environmental Psychology* 10:121–134.

Pidgeon, Nick F, Roger E Kasperson, and Paul Slovic (eds.). 2003. *The Social Amplification of Risk*. Cambridge UK: Cambridge University Press.

Pidgeon, Nick F, Irene Lorenzoni, and Wouter Poortinga. 2008. "Climate change or nuclear power—No thanks! A quantitative study of public perceptions and risk framing in Britain." *Global Environmental Change* 18:69–85.

Pidgeon, Nick F, Wouter Poortinga, Gene Rowe, Tom Horlick-Jones, John Walls, and Tim O'Riordan. 2005. "Using Surveys in Public Participation Processes for Risk Decision Making: The Case of the 2003 British GM Nation? Public Debate." *Risk Analysis* 25:467–479.

Poortinga, Wouter, Midori Aoyagi, and Nick F Pidgeon. 2013. "Public perceptions of climate change and energy futures before and after the Fukushima accident: A comparison between Britain and Japan." *Energy Policy* 62:1204–1211.

Popper, Karl R. 1959. *The Logic of Scientific Discovery*. London: Hutchinson.

Popper, Karl R. 1982. *The Open Universe*. Totowa, NJ: Rowan and Littlefield.

Preisendörfer, Peter. 1999. Umwelteinstellungen und Umweltverhalten in Deutschland: *Empirische Befunde und Analysen auf der Grundlage der Bevölkerungsumfragen „Umweltbewusstsein in Deutschland 1991-1998"*. Opladen: Leske und Budrich.

Putnam, Robert D. 1993. *Making Democracy Work: Civic Traditions in Modern Italy*. Princetion, NJ: Princeton University Press.

Putnam, Robert D. 1995. "Tuning In, Tuning Out: The Strange Disappearance of Social Capital in America." *PS: Political Science and Politics* 28:664–683.

Rappaport, Roy A. 1996. "Risk and the Human Environment." *Annals of the American Academy of the Political and Social Sciences* 545:64–74.

Rayner, Steve. 1988. "Muddling Through Metaphors to Maturity: A Commentary on Kasperson et al., The Social Amplification of Risk." *Risk Analysis* 8:201–204.

Rayner, Steve. 1990. *Risk in Cultural Perspective: Acting under Uncertainty*. Dordrecht: Kluwer.

Rayner, Steve. 1992. "Cultural theory and risk analysis." In *Social Theories of Risk*, edited by Sheldon Krimsky and Dominic Golding, pp. 83–115. Westport, CT: Praeger.

Rayner, Steve and Robin Cantor. 1987. "How Fair Is Safe Enough? The Cultural Approach to Societal Technology Choice." *Risk Analysis* 7:3–9.

Reardon, Candice A and Kaymarlin Govender. 2013. "Masculinities, cultural worldviews and risk perceptions among South African adolescent learners." *Journal of Risk Research* 16:753–770.

Renn, Ortwin. 1990. "Public Responses to the Chernobyl Accident." *Journal of Environmental Psychology* 10:151–167.

Renn, Ortwin. 1992. "Risk communication: Towards a rational discourse with the public." *Journal of Hazardous Materials* 29:465–519.

Renn, Ortwin. 1998. "Three decades of risk research: accomplishments and new challenges." *Journal of Risk Research* 1:49–71.

Renn, Ortwin. 2008. *Risk Governance: Coping with Uncertainty in a Complex World*. London: Earthscan.

Renn, Ortwin. 2010. "The contribution of different types of knowledge towards understanding, sharing and communication risk concepts." *Catalan Journal of Communication & Cultural Studies* 2:177–195.

Renn, Ortwin, William J Burns, Jeanne X Kasperson, Roger E Kasperson, and Paul Slovic. 1992. "The Social Amplification of Risk: Theoretical Foundations and Empirical Applications." *Journal of Social Issues* 48:137–160.

Renn, Ortwin and D Levine. 1991. "Credibility and trust in risk communication." In *Communicating Risk to the Public*, edited by Roger E Kasperson and Pieter Jan Stallen, pp. 175–218. Dortrecht, The Netherlands: Kluwer Academic Publishers.

Renn, Ortwin and Bernd Rohrmann (eds.). 2000a. *Cross-Cultural Risk Perception: A Survey of Empirical Studies*. Technology; Risk, and Society. Dordrecht: Kluwer Academic Publisher.

Renn, Ortwin and Bernd Rohrmann. 2000b. "Cross-Cultural Risk Perception Research: State and Challenges." In *Cross-Cultural Risk Perception: A Survey of Empirical Studies*, edited by Ortwin Renn and Bernd Rohrmann, pp. 211–234. Dordrecht: Kluwer Academic Publisher.

Renn, Ortwin, Thomas Webler, Horst Rakel, Peter Dienel, and Branden Johnson. 1993. "Public Participation in Decision Making: A Three-Step Procedure." *Policy Sciences* 26:189–214.

Rilke, Rainer Maria. 2005. *Rilke's Book of Hours: Love Poems to God*. New York: Riverhead Books.

Rip, Arie. 1988. "Should Social Amplification of Risk Be Counteracted?" *Risk Analysis* 8:193–197.

Rippl, Susanne. 2002. "Cultural theory and risk perception: a proposal for a better measurement." *Journal of Risk Research* 5:147–165.

Risse-Kappen, Thomas. 1991. "Public Opinion, Domestic Structure, and Foreign Policy in Liberal Democracies." *World Politics* 43:479–512.

Rohrmann, Bernd. 1994. "Risk Perception of Different Societal Groups: Australian Findings and Crossnational Comparisons." *Australian Journal of Psychology* 46:150–163.

Rohrmann, Bernd and Ortwin Renn. 2000. "Risk Perception Research: An Introduction." In *Cross-Cultural Risk Perception: A Survey of Empirical Studies*, edited by Ortwin Renn and Bernd Rohrmann, pp. 11–53. Dordrecht: Kluwer Academic Publisher.

Rokeach, Milton. 1960. "The open and closed mind." Basic Books, New York.

Rosa, Eugene A. 1998. "Metatheoretical Foundations for Post-normal Risk." *Journal of Risk Research* 1:15–44.

Rosa, Eugene A, Thomas Dietz, Richard H Moss, Scott Atran, and Susanne Moser. 2012. "Managing the Risks of Climate Change and Terrorism." *Solutions* 3:59–65.

Rosa, Eugene A, Noriyuki Matsuda, and Randall R Kleinhesselink. 2000. "The Cognitive Architecture of Risk: Pancultural Unity or Cultural Shaping?" In *Cross-Cultural Risk Perception: A Survey of Empirical Studies*, edited by Ortwin Renn and Bernd Rohrmann, pp. 185–210. Dordrecht: Kluwer Academic Publisher.

Rosa, Eugene A, Ortwin Renn, and Aaron M McCright. 2014. *The Risk Society* Revisited. Social Theory and Governance. Philadelphia: Temple University Press.

Rottenstreich, Yuval and Christopher K Hsee. 2001. "Money, Kisses, and Electric Shocks: On the Affective Psychology of Risk." *Psychological Science* 12:185–190.

Rottenstreich, Yuval and Amos Tversky. 1997. "Unpacking, repacking, and anchoring: Advances in support theory." *Psychological Review* 104:406–415.

Rucht, Dieter. 1990. "Campaigns, skirmishes and battles: anti-nuclear movements in the USA, France and West Germany." *Industrial Crisis Quarterly* 4:193–222.

Rüdig, Wolfgang. 1990. *Anti-Nuclear Movements. A World Survey of Opposition to Nuclear Energy*. Essex: Longman.

Schneider, Mycle. 2008. "Nuclear Power in France: Beyond the Myth." *Greens-EFA Group in the European Parliament* .

Searle, John R. 1998. *Mind, Language and Society. Philosophy in the Real World*. New York: Basic Book.

Shanteau, James. 1978. "When Does a Response Error Become a Judgmental Bias? Commentary on "Judged Frequency of Lethal Events."." *Journal of Experimental Psychology: Human Learning and Memory* 4:579–581.

Shields, Todd and Ka Zeng. 2012. "The Reverse Environmental Gender Gap in China: Evidence from 'The China Survey'." *Social Science Quarterly (Wiley-Blackwell)* 93:1–20.

Short, Jr, James F. 1989. "On Defining, Describing, and Explaining Elephants (and Reactions to Them): Hazards, Disasters, and Risk Analysis." *International Journal of Mass Emergencies and Disasters* 7:397–418.

Short, Jr, James F. 1992. "Defining, explaining, and managing risk." In *Organizations, Uncertainties and Risk*, edited by James F Short, Jr and Lee Clarke, pp. 3–23. Boulder, CO: Westview Press.

Siegrist, Michael. 2014. "Longitudinal Studies on Risk Research." *Risk Analysis* 34:1376–1377.

Siegrist, Michael and George Cvetkovich. 2000. "Perception of Hazards: The Role of Social Trust and Knowledge." *Risk Analysis* 20:713–720.

Siegrist, Michael, George Cvetkovich, and Claudia Roth. 2000. "Salient Value Similarity, Social Trust, and Risk/Benefit Perception." *Risk Analysis* 20:353–362.

Siegrist, Michael, Carmen Keller, and Henk A L Kiers. 2005. "A New Look at the Psychometric Paradigm of Perception of Hazards." *Risk Analysis* 25:211–222.

Siegrist, Michael and Bernadette Sütterlin. 2014. "Human and Nature-Caused Hazards: The Affect Heuristic Causes Biased Decisions." *Risk Analysis* 34:1482–1494.

Siegrist, Michael, Bernadette Sütterlin, and Carmen Keller. 2014. "Why have some people changed their attitudes toward nuclear power after the accident in Fukushima?" *Energy Policy* 69:356–363.

Siegrist, Michael and Vivianne H M Visschers. 2013. "Acceptance of nuclear power: The Fukushima effect." *Energy Policy* 59:112–119.

Simon, Herbert A. 1956. "Rational Choice and the Structure of the Environment." *Psychological Review* 63:129–138.

Simon, Herbert A. 1982. *Models of Bounded Rationality*. Cambridge, MA: MIT Press.

Simon, Richard M. 2013. "Roles or Values? Gender Differences in Opposition to Nuclear Power." *International Journal of Humanities and Social Science* 3:27–38.

Sjöberg, Lennart. 1995. *Explaining Risk Perception: An Empirical and Quantitative Evaluation of Cultural Theory* . Rhizikon: Risk Research Reports, No. 22, Centre for Risk Research, University of Stockholm, Sweden.

Sjöberg, Lennart. 2000. "Factors in Risk Perception." *Risk Analysis* 20:1–12.

Sjöberg, Lennart. 2001. "Limits of Knowledge and the Limited Importance of Trust." *Risk Analysis* 21:189–198.

Sjöberg, Lennart. 2002. "Attitudes toward technology and risk: Going beyond what is immediately given." *Policy Sciences* 35:379.

Sjöberg, Lennart. 2006. "Rational Risk Perception: Utopia or Dystopia?" *Journal of Risk Research* 9:683–696.

Slovic, Paul. 1987. "Perception of Risk." *Science, New Series* 236:280–285.

Slovic, Paul. 1993. "Perceived Risk, Trust, and Democracy." *Risk Analysis* 13:675–682.

Slovic, Paul. 1999. "Trust, Emotion, Sex, Politics, and Science: Surveying the Risk-Assessment Battlefield." *Risk Analysis* 19:689–701.

Slovic, Paul. 2000a. *The Perception of Risk*. London: Earthscan.

Slovic, Paul. 2000b. "Trust, Emotion, Sex, Politics and Science: Surveying the Risk-assessment Battlefield." In *The Perception of Risk*, edited by Paul Slovic, pp. 390–412. London: Earthscan.

Slovic, Paul. 2010. *The Feeling of Risk: New Perspectives on Risk Perception*. London: Earthscan.

Slovic, Paul, Melissa L Finucane, Ellen Peters, and Donald G MacGregor. 2002. "The Affect Heuristic." In *Heuristics and biases: the psychology of intuitive judgement*, edited by Thomas Gilovich, Dale Griffin, and Daniel Kahneman, pp. 397–420. New York: Cambridge University Press.

Slovic, Paul, Melissa L Finucane, Ellen Peters, and Donald G MacGregor. 2004. "Risk as Analysis and Risk as Feelings: Some Thoughts about Affect, Reason, Risk, and Rationality." *Risk Analysis* 24:311–322.

Slovic, Paul, Melissa L Finucane, Ellen Peters, and Donald G MacGregor. 2007. "The affect heuristic." *European Journal of Operational Research* 177:1333–1352.

Slovic, Paul, B Fischhoff, Sarah Lichtenstein, and F J C Roe. 1981. "Perceived Risk: Psychological Factors and Social Implications [and Discussion]." *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences* 376:17–34.

Slovic, Paul, James Flynn, C K Mertz, Marc Poumadère, and Claire Mays. 2000a. "Nuclear Power and the Public: A Comparative Study of Risk Perception in France and the United States." In *Cross-Cultural Risk Perception: A Survey of Empirical Studies*, edited by Ortwin Renn and Bernd Rohrmann, pp. 55–102. Dordrecht: Kluwer Academic Publisher.

Slovic, Paul, Mark Layman, Nancy Kraus, James Flynn, James Chalmers, and Gail Gesell. 1991. "Perceived Risk, Stigma, and Potential Economic Impacts of a High-Level Nuclear Waste Repository in Nevada." *Risk Analysis* 11:683–696.

Slovic, Paul, Sarah Lichtenstein, and Baruch Fischhoff. 1984. "Modeling the Societal Impact of Fatal Accidents." *Management Science* 30:464–474.

Slovic, Paul, Torbjörn Malmfors, C K Mertz, Nancy Neil, and Iain FH Purchase. 1997. "Evaluating chemical risks: results of a survey of the British Toxicology Society." *Human & Experimental Toxicology* 16:289–304.

Slovic, Paul, John Monahan, and Donald G MacGregor. 2000b. "Violence Risk Assessment and Risk Communication: The Effects of Using Actual Cases, Providing Instruction, and Employing Probability Versus Frequency Formats." *Law and Human Behavior* 24:271–96.

Smithson, Michael. 1989. *Ignorance and Uncertainty : Emerging Paradigms*. New York: Springer-Verlag.

Smithson, Michael. 1997. "Judgment under Chaos." *Organizational Behavior and Human Decision Processes* 69:58–66.

Smithson, Michael. 2008. "Psychology's Ambivalent View of Uncertainty." In *Uncertainty and Risk: Multidisciplinary Perspectives*, edited by Gabriele Bammer and Michael Smithson, pp. 205–218. London: Earthscan.

Smola, Karen Wey and Charlotte D Sutton. 2002. "Generational Differences: Revisiting Generational Work Values for the New Millennium." *Journal of Organizational Behavior* 23:363–382.

Solomon, Lawrence S, Donald Tomaskovic-Devey, and Barbara J Risman. 1989. "The Gender Gap and Nuclear Power: Attitudes in a Politicized Environment ." *Sex Roles* 21:401–414.

Sparks, Paul and Richard Shepherd. 1994. "Public Perceptions of the Potential Hazards Associated with Food Production and Food Consumption: An Empirical Study." *Risk Analysis* 14:799–806.

Starr, Chauncey. 1969. "Social Benefit versus Technological Risk." *Science* 165:1232–1238.

Stern, Paul C and Thomas Dietz. 1994. "The Value Basis of Environmental Concern." *Journal of Social Issues* 50:65–84.

Stern, Paul C, Thomas Dietz, and Linda Kalof. 1993. "Value Orientations, Gender, and Environmental Concern." *Environment and Behavior* 25:322–348.

Stern, Paul C, Linda Kalof, and Thomas Dietz. 1995. "Values, Beliefs, and Proenvironmental Action: Attitude Formation Toward Emergent Attitude Objects." *Journal of Applied Social Psychology* .

Stout-Wiegand, Nancy and Roger B Trent. 1983. "Sex Differences in Attitudes toward New Energy Resource Developments." *Rural Sociology* 48:637–646.

Stoutenborough, James W, Shelbi G Sturgess, and Arnold Vedlitz. 2013. "Knowledge, risk, and policy support: Public perceptions of nuclear power." *Energy Policy* 62 IS -:176–184.

Taleb, Nassim Nicholas. 2010. *The Black Swan: The Impact of the Highly Improbable*. London: Penguin Books, 2 edition.

Tansey, James. 2004. "Risk as politics, culture as power." *Journal of Risk Research* 7:17–32.

Tetlock, Philip E. 2002. "Social Functionalist Frameworks for Judgment and Choice: Intuitive Politicians, Theologians, and Prosecutors." *Psychological Review* 109:451–471.

Thompson, Michael. 1980. "An Outline of the Cultural Theory of Risk." *IIASA Working Paper WP-80-177, of the International Institute for Applied Systems Analysis* .

Thompson, Michael, Richard Ellis, and Aaron Wildavsky. 1990. *Cultural Theory*. Boulder, CO: Westview Press.

Trumbo, Craig W. 1996. "Examining Psychometrics and Polarization in a Single-Risk Case Study." *Risk Analysis* 16:429–438.

Turner, Barry A. 1978. *Man-Made Disasters: The Failure of Foresight*. London: Wykeham.

Turner, Barry A and Nick F Pidgeon. 1997. *Man-Made Disasters*. Oxford: Butterworth-Heinemann.

Tversky, Amos. 1972. "Elimination by Aspects: A Theory of Choice." *Psychological Review* 79:281–299.

Tversky, Amos and Daniel Kahneman. 1973. "Availability: a Heuristic for Judging Frequency and Probability." *Cognitive Psychology* 5:207–232.

Tversky, Amos and Daniel Kahneman. 1974. "Judgment Under Uncertainty: Heuristics and Biases." *Science* 185:1124–1131.

Tversky, Amos and Daniel Kahneman. 1981. "The Framing of Decisions and the Psychology of Choice." *Science* 211:453–458.

Tversky, Amos and Daniel Kahneman. 1982. "The framing of decisions and the psychology of choice." In *Judgement under uncertainty: Heuristics and biases*, edited by Robin M Hogarth, pp. 3–20. Cambridge: Cambridge University Press.

Ungar, Sheldon. 2000. "Knowledge, ignorance and the popular culture: climate change versus the ozone hole." *Public Understanding of Science* 9:297–312.

van Asselt, Marjolein B A and Ortwin Renn. 2011. "Risk governance." *Journal of Risk Research* 14:431–449.

Van Der Pligt, J and Cees J H Midden. 1990. "Chernobyl: Four Years Later: Attitudes, Risk Management and Communication." *Journal of Environmental Psychology* 10:91–99.

Van Liere, Kent D. and Riley E. Dunlap. 1980. "The Social Bases of Environmental Concern: A Review of Hypotheses, Explanations and Empirical Evidence." 44:181–197.

Vaughan, Elaine. 1995. "The Significance of Socioeconomic and Ethnic Diversity for the Risk Communication Process." *Risk Analysis* 15:169–180.

Vaughan, Elaine and Brenda Nordenstam. 1991. "The Perception of Environmental Risks among Ethnically Diverse Groups." *Journal of Cross-Cultural Psychology* 22:29–60.

Vaughan, Elaine and Marianne Seifert. 1992. "Variability in the Framing of Risk Issues." *Journal of Social Issues* 48:119–135.

Veldman, Meredith. 1994. *Fantasy, the Bomb, and the Greening of Britain: Romantic Protest, 1945-1980*. Cambridge: Cambridge University Press.

Verplanken, Bas. 1989. "Beliefs, Attitudes, and Intentions Toward Nuclear Energy Before and After Chernobyl in a Longitudinal Within-subjects Design." *Environment and Behavior* 21:371–392.

Viklund, Mattias J. 2003. "Trust and Risk Perception in Western Europe: A Cross-National Study." *Risk Analysis* 23:727–738.

Visschers, Vivianne H M and Michael Siegrist. 2013. "How a Nuclear Power Plant Accident Influences Acceptance of Nuclear Power: Results of a Longitudinal Study Before and After the Fukushima Disaster." *Risk Analysis* 33:333–347.

Vogl, Dominikus. 2014. "Der Einfluss der Reaktorkatastrophe auf das nukleare Risikobewusstsein und das allgemeine Umweltbewusstsein in der Bevölkerung." In *Fukushima und die Folgen. Medienberichterstattung, Öffentliche Meinung, Politische Konsequenze*, edited by Jens Wolling and Dorothee Arlt, pp. 323–340. Ilmenau: Universitaetsverlag Ilmenau.

Wachinger, Gisela, Ortwin Renn, Chloe Begg, and Christian Kuhlicke. 2013. “The Risk Perception Paradox—Implications for Governance and Communication of Natural Hazards.” *Risk Analysis* 33:1049–1065.

Wahlberg, Anders A F and Lennart Sjöberg. 2000. “Risk perception and the media.” *Journal of Risk Research* 3:31–50.

Walker, Brian and David Salt. 2006. *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*. Washington, DC: Island Press.

Walters, James W. 2003. *Martin Buber & Feminist Ethics. The Priority of the Personal*. Syracuse, NY: Syracuse University Press.

Webler, Thomas. 1999. “The craft and theory of public participation: a dialectical process.” *Journal of Risk Research* 2:55–71.

Weinberg, Alvin M. 1956. “Today’s Revolution.” *Bulletin of the Atomic Scientists* October:299–302.

Weinberg, Alvin M. 1972. “Social Institutions and Nuclear Energy.” *Science* 177:27–34.

Weinberg, Alvin M. 1980. “Is Nuclear Energy Necessary?” *Proceedings of the American Philosophical Society* 124:399–403.

Whitfield, Stephen C, Eugene A Rosa, Amy Dan, and Thomas Dietz. 2009. “The Future of Nuclear Power: Value Orientations and Risk Perception.” *Risk Analysis* 29:425–437.

Wiernik, Brenton M, Deniz S Ones, and Stephan Dilchert. 2013. “Age and environmental sustainability: a meta-analysis.” *Journal of Managerial Psychology* 28:826–856.

Wildavsky, Aaron and Karl Dake. 1990. “Theories of Risk Perception: Who Fears What and Why?” *Daedalus* 119:41–60.

Wiliarty, Sarah Elise. 2013. “Nuclear Power in Germany and France.” *Polity* 45:281–296.

Williams, Richard. 2012. “Using the margins command to estimate and interpret adjusted predictions and marginal effects.” *Stata Journal* 12:308–331.

Wilson, Timothy D and Jonathan W Schooler. 1991. “Thinking too much: Introspection can reduce the quality of preferences and decisions.” *Journal of Personality and Social Psychology* 60:181–192.

Wolling, Jens and Dorothee Arlt (eds.). 2014. *Fukushima und die Folgen. Medienberichterstattung, Öffentliche Meinung, Politische Konsequenzen*. Ilmenau: Universitaetsverlag Ilmenau.

Wynne, Brian. 1992a. “Risk and Social Learning: Reification to Engagement.” In *Social Theories of Risk*, edited by Sheldon krimsky and Dominic Golding, pp. 275–297. Westport: Praeger Publishers.

Wynne, Brian. 1992b. "Uncertainty and environmental learning: Reconceiving science and policy in the preventive paradigm." *Global Environmental Change* 2:111–127.

Xiao, Chenyang and Riley E. Dunlap. 2007. "Validating a Comprehensive Model of Environmental Concern Cross-Nationally: A U.S.-Canadian Comparison." *Social Science Quarterly* 88:471–493.

Xiao, Chenyang and Aaron M McCright. 2007. "Environmental Concern and Sociodemographic Variables: A Study of Statistical Models." *The Journal of Environmental Education* 38:3–14.

Yang, Chi-Jen. 2011. "A comparison of the nuclear options for greenhouse gas mitigation in China and in the United States." *Energy Policy* 39:3025–3028.

Zajonc, R B. 1980. "Feeling and Thinking: Preferences Need No Inferences." *American Psychologist* 35:151–175.

Zwick, Michael M and Ortwin Renn. 2002. "Perception and Evaluation of Risks: Findings of the Baden-Württemberg Risk Survey 2001." *Center of Technology Assessment in Baden-Würtemberg, Stuttgart, Germany* Working paper no 203.

Selbständigkeitserklärung

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Berlin, 17. Juli 2016 Dominikus Vogl